

## **1.0 INTRODUCTION**

### **1.1 Site Regulatory History**

On January 21, 1999, Solutia Inc. (Solutia) entered into an Administrative Order by Consent (AOC) with Region 5 of the United States Environmental Protection Agency (USEPA) to perform an Engineering Evaluation/Cost Analysis (EE/CA) for soil, sediment, surface water and air and a Remedial Investigation/Feasibility Study (RI/FS) for groundwater at Sauget Area 1 (USEPA, 1999a). Sauget Area 1 ("the Site") is located just east of the Mississippi River within the Villages of Sauget and Cahokia, Saint Clair County, Illinois. The Site consists of four closed disposal areas (Sites G, H, I and N), a backfilled impoundment (Site L), an inactive borrow pit (Site M) and Dead Creek (Figures 1-1, 1-2 and 1-3).

USEPA issued a time-critical removal action order (UAO) on June 21, 1999 to replace culverts in Dead Creek (USEPA, 1999b). This order was modified on May 31, 2000 to include removal of sediments from Creek Segments B, C, D and E and amended on August 29, 2001 to include removal of sediments from Creek Segment F including the Borrow Pit Lake. As described in Section 2.3.2, Solutia excavated 46,000 cubic yards of sediments from Creek Segments B, C, D, E and F in 2001/2002 and 5,028 cubic yards of creek bottom soils and 7,315 cubic yards of sediments, respectively, from Creek Segments B, D and E and the Borrow Pit Lake in 2005/2006 under this order (Figure 1-4). Excavated sediments were transferred to an on-site RCRA and TSCA-compliant containment cell constructed adjacent to the west bank of Dead Creek just north of Judith Lane (Figure 1-2).

Table 1-1 provides a general site timeline of regulatory orders, remedial actions, site investigations, and human health and ecological risk assessments at Sauget Area 1.

### **1.2 Site Investigation History**

#### **1.2.1 Remedial Investigation**

In 1999, Solutia prepared a Support Sampling Plan (SSP) in order to implement the site characterization actions required by the AOC Scope of Work (SOW) and provide the data necessary to support completion of both the EE/CA and the RI/FS (Solutia, 1999). USEPA approved this work plan on September 9, 1999. The overall objective of the Sauget Area 1 site characterization process was to further determine the extent of contamination at the Site beyond that defined by previous Site investigations and provide the data needed to evaluate the impact to soil, groundwater, sediments, surface water and air resulting from migration from the Sauget Area 1 source areas. Data and information from this site characterization process were then used to prepare a human health risk assessment (ENSR, 2001) and an ecological risk assessment (Menzie-Cura, 2001). Affected media were investigated in sufficient detail to support informed risk management decisions that would address the impact to human health and/or to the environment from affected media at the Site during the EE/CA and RI/FS remedy evaluation process.

Data gaps identified by the USEPA in the AOC SOW and by a review of two Ecology and Environment reports, one prepared for IEPA (Ecology and Environment, 1988) and one prepared for USEPA (Ecology

and Environment, 1998), were addressed by implementation of the Support Sampling Plan. Because these previous investigations were conducted more than 10 years prior to the start of the SSP implementation, a considerable amount of new data was collected from all media at the Site. However, some of these historical data, specifically waste characterization data from Sites G, H, I, L, M and N, were also used to fill gaps in the information collected during the SSP investigation.

Support Sampling Plan field work started in the third quarter of 1999 (3Q99) and was completed in the second quarter of 2000 (2Q00). Data collected during implementation of the SSP to fill data gaps and provide information for the HHRA, ERA, EE/CA and RI/FS are described below. A Data Report, containing analytical data for the waste, soil, groundwater, sediment, surface water, biota and air samples collected during implementation of the SSP, was submitted to USEPA in January 2001 (O'Brien and Gere, 2001).

**Disposal Area Characterization** - Surface soil and subsurface soil/waste samples were collected from borings installed at each of the disposal areas (Sites G, H, I, L and N) in order to characterize the depth and types of wastes present at each site and to evaluate potential exposures for the Human Health Risk Assessment including the outdoor industrial worker and construction/utility worker exposure scenarios (Figure 1-3). Additional activities included determination of disposal area boundaries using historical air photo analysis, soil gas surveys and test trenching and identification of buried tanks and/or drums using magnetometer surveys and test trenches.

Ambient air sampling was conducted upwind and downwind of Sites G, H, I and L to determine the tendency of Site constituents to enter the atmosphere and local wind patterns. Air sampling data were subsequently evaluated in the HHRA outdoor industrial worker, construction/utility worker and trespassing teenager exposure scenarios.

Treatability studies were planned for disposal area soils and wastes in order to identify any characteristics that would prevent their treatment using off-site incineration or on-site thermal desorption technologies. Vendors of these technologies indicated that these materials were not amenable to treatment by incineration or thermal desorption. Therefore, the planned disposal area soil and waste treatability studies were not performed. Leachate treatability studies were performed to determine the appropriate combination of physical/chemical and/or biological treatment processes needed to achieve pretreatment requirements for discharge to the American Bottoms Regional Treatment Facility (ABRTF).

**Groundwater Sampling** - Groundwater samples were collected to define the horizontal and vertical distribution of constituents in the alluvial aquifer beneath and downgradient of Site I and Sites G, H and L (Figure 1-3) and provide information for two HHRA exposure scenarios - volatilization from ground water to outdoor air for the outdoor industrial worker and construction/utility worker, and vapor intrusion into buildings for the indoor industrial worker. In addition, groundwater samples were collected from weathered bedrock beneath Sites G, H and I to determine the vertical extent of migration from these source areas.

Alluvial aquifer groundwater samples were also collected downgradient of Creek Segment B and Site M. Site N was not included in the groundwater sampling program because historical information on waste

disposal activities and historical soil and groundwater data did not indicate a potential for groundwater impact from this disposal area.

Shallow groundwater samples were collected from non-potable domestic water-supply wells located along Judith Lane to assess any potential adverse impacts of residential use of groundwater for lawn and garden watering scenarios in the HHRA. In addition, shallow groundwater samples were collected adjacent to Site M at the end of Walnut Street and the east bank of Dead Creek at Judith Lane to determine their effect on groundwater quality.

Background groundwater samples were collected upgradient of the disposal areas to determine if constituents were migrating into Sauget Area 1 from source areas to the east (upgradient) of the Site.

Groundwater flow direction was determined by installing water-level measurement piezometers in each of the three hydrogeologic units present in Sauget Area 1 and measuring groundwater-level elevations in 3Q99, 4Q99, 1Q00 and 2Q00. Aquifer hydraulic conductivity was measured by conducting slug tests in piezometers completed in each of the hydrogeologic units. Aquifer grain size analyses were also performed on soil samples collected from each hydrogeologic unit.

**Surface Water, Sediment and Biota Sampling** - Surface water, sediment and biota samples were collected in Dead Creek, the Borrow Pit Lake, Prairie du Pont Creek and two Reference Areas (Figure 1-4) to determine the extent of downstream migration of site-related constituents and provide information for use in the HHRA (recreational teenager and recreational fishing exposure scenarios) and the ERA (potential ecological receptor exposures).

Biota sampling included collection of tissue samples and performance of sediment bioassays. Tissue samples were collected from fish (large-mouth bass, brown bullheads and forage fish), clams, shrimp and plants in order to evaluate the impact of site-related constituents on potential ecological receptors (i.e., large mouth bass, great blue herons, bald eagles, mallard ducks, muskrats and river otters). Fish filet data were also used in the HHRA (recreational fishing scenario). Bioassays were performed on sediment samples using sensitive test organisms (*Hyalella azteca* and *Chironomus tentans*) to determine the effects of impacted sediments on organism survival, growth and reproduction.

Surface water, sediment and biota data were collected in 1999/2000 prior to performance of the time-critical sediment and soil removal action. Surface water and sediment data are discussed in this report and the biota data are included in the January 2001 Support Sampling Plan Data Report (O'Brien & Gere, 2001) and the June 2001 Ecological Risk Assessment (Menzie-Cura & Associates, 2001).

**Floodplain Soil Sampling** - Surface and subsurface floodplain soil samples were collected within the developed area of Dead Creek bounded by Queeny Road on the north, Falling Springs Road on the east, Route 157 on the south and Route 3 (Mississippi Avenue) on the west (Figure 1-4). Floodplain soil samples were collected in areas susceptible to flooding to determine the extent of overbank transport of impacted sediments. There is no historical knowledge of overbank flooding of Dead Creek. Overbank flooding of Dead Creek is very unlikely because the Metro East Sanitary District pumping station at Prairie du Pont Creek controls discharge from Dead Creek. Floodplain soil sampling was also performed to

assess airborne transport of impacted sediments because Dead Creek is an intermittent stream that is frequently dry during warm weather conditions.

Information from the floodplain soil sampling program was used to determine the extent of migration due to overbank flooding and wind-blown dust deposition. In addition, surficial and subsurface soil information was used in the HHRA to evaluate outdoor industrial worker, construction/utility worker and residential exposure scenarios and in the ERA to assess risks to terrestrial organisms. Background soil samples were also collected as part of this sampling program.

### **1.2.2 Supplemental Remedial Investigation**

After completion of the Remedial Investigation, a number of supplemental remedial investigations were performed to collect information needed to complete the Sauget Area 1 site characterization process. Most of these supplemental investigations focused on source areas but additional investigations were performed for groundwater and creek bottom soil.

#### **1.2.2.1 Source Area Investigations**

USEPA performed test trenching and soil, waste and groundwater sampling at Sites H, I, L and N in 2002 and 2003 to look for buried tanks and drums and to identify the presence of contaminants in these disposal areas (Tetra Tech, 2003a, 2003b and 2003c). Solutia investigated surface soils at Site G in 2004 after wastes were found at the surface of the site during performance of a geophysical survey (Golder, 2004).

Solutia performed the following five supplemental remedial investigations in Sauget Area 1 to characterize source areas and migration pathways that were not evaluated during the Remedial Investigation:

- DNAPL Characterization and Remediation Study at Sites G, H and I in 2004/2005 (GSI, 2006c) to identify the volume of DNAPL-containing aquifer materials beneath these sites;
- DNAPL Recovery Study at Site I in 2007/2008 (GSI, 2008a) to determine whether or not pooled DNAPL at Site I was recoverable;
- Flux Study at Sites G, H, I and L in 2005 (GSI, 2005) to determine mass flux from the disposal areas and the underlying DNAPL-containing aquifer matrix and identify the primary source of site-related constituents entrained in groundwater and migrating downgradient;
- Soil Vapor Investigation in 2006 (Golder Associates, 2007a) to sample soil vapors at the Sauget Village Hall, Cerro Flow Products and Wiese, Inc. and provide information for the HHRA (vapor intrusion into occupied buildings); and
- Utility Corridor Investigation in 2007 (Golder Associates, 2008) to characterize soils and wastes present in the utility corridors on either side of Queeny Avenue adjacent to Sites I and H and provide information for the HHRA (construction/utility worker exposure scenario); and

### 1.2.2.2 Groundwater Investigations

**Regional Groundwater Model Sampling** - During Phase 1 of the Sauget Area 2 Supplemental Remedial Investigation, groundwater samples were collected from monitoring wells throughout the region, including monitoring wells at Sauget Area 2 sites, Sauget Area 1 sites, the W.G. Krummrich facility and ConocoPhillips bulk storage terminal. In addition, groundwater samples were collected from 26 groundwater monitoring wells installed during Phase 2 of the Sauget Area 2 Supplemental Remedial Investigation. Monitoring wells sampled in Sauget Area 1 included BR-G, BR-H, EE-01, EE-03, EEG-107, IMW-1S, IMW-1M AND IMW-1D. Groundwater quality data from these 2005/2006 sampling programs were used for calibration of the regional groundwater model (GSI, 2008b).

**Soil to Groundwater Leaching Investigation** - Groundwater samples were collected in the SHU downgradient of the highest detected cadmium concentrations in Dead Creek Segments C, D, E and F to determine if leaching from creek bottom soil to groundwater was a migration pathway (Golder Associates, 2007b).

### 1.2.2.3 Creek Bottom Soil Investigations

**Post Sediment-Removal Creek Bottom Soil Investigation**- After completion of sediment removal in Dead Creek in 2001, creek bottom soil samples were collected in Creek Segments B, C, D, E and F to characterize residual constituent concentrations and provide information for the Dead Creek Final Remedy HHRA (ENSR, 2001 and ENSR, 2002) and ERA (Menzie-Cura, 2002). In 2003, sediment samples were collected in the Borrow Pit Lake upstream and downstream of the confluence of the channel portion of Creek Segment F (Solutia, 2008b).

**Post Soil-Removal Creek Bottom Soil Investigation** - Creek bottom soils were removed in Creek Segments B (2005), Creek Segment D (2006), Creek Segment E (2006), Creek Segment F (2006) and the Borrow Pit Lake (2006) to achieve site-specific, risk-based concentrations for the protection of forage fish (i.e., small fish which serve as food for predatory fish and birds) or site-specific, soil to groundwater leaching criteria. Confirmatory samples were collected in all four creek segments and the Borrow Pit Lake to demonstrate that criteria were achieved (Solutia, 2008b).

## 1.3 Remedial Investigation Report Purpose and Organization

In order to streamline the Sauget Area 1 remedy selection and implementation, the January 21, 1999 AOC divided the site characterization and remedy evaluation process into two components: 1) an Engineering Evaluation/Cost Analysis (EE/CA) for soil, sediment, surface water and air and 2) a Remedial Investigation/Feasibility Study (RI/FS) for groundwater. When the June 21, 1999 UAO for a time-critical removal action in Dead Creek was modified on May 31, 2000 to include sediment removal in Creek Segments B, C, D and E and amended on August 29, 2001 to include removal of sediments from Creek Segment F including the Borrow Pit Lake, a streamlined remedy-selection process was no longer necessary because removal of sediments from Dead Creek in 2001/2002 addressed any immediate threats to public health and the environment from exposure to impacted sediments and surface water. Completion of human health risk assessments (ENSR, 2001, 2002 and 2006) and ecological risk

assessments (Menzie-Cura, 2001 and 2002) for Sauget Area 1 confirmed that any immediate threats to public health and the environment were controlled by the time-critical removal action and demonstrated that a two-component site characterization and remedy evaluation process was no longer appropriate. As a result, the RI focus was expanded. Thus, environmental media originally included in the EE/CA but not addressed by the time-critical removal action (i.e. soil and air) is included in this RI for groundwater.

The Remedial Investigation Report (RI Report) is found in Sections 2.0 through 9.0 of this document. It presents the information collected for the Support Sampling Plan, including sediment and surface water sampling, as well as the information collected after completion of the SSP. The biota sampling data was excluded from the RI report because it was already presented and evaluated in the Ecological Risk Assessment (Menzie-Cura & Associates, 2001).

Section 1.0 provides an introduction of the project and states the project objectives, technical approach, and outline of this document. Section 2.0 discusses Sauget Area 1 location and description, physical characteristics and removal and remedial actions, and the Sauget Area 2 Groundwater Migration Control System (GMCS). Section 3.0 presents the results of the 1999 to 2000 Remedial Investigation and Section 4.0 summarizes the 2002 to 2008 Supplemental Remedial Investigation. Sections 5.0 and 6.0 discuss, respectively, the nature and extent of contamination and contaminant fate and transport. Section 7.0 presents a Conceptual Site Model developed from data collected for the Remedial Investigation and the Supplemental Remedial Investigation. Section 8.0 presents a summary of the various human health risk assessments that were conducted. Section 9.0 summarizes ecological risk assessment activities and results.

Several companies were involved in preparation of the Remedial Investigation Report. Solutia was the primary author of Sections 1.0, 2.0, and 3.0, GSI Environmental wrote Sections 4.0 through 7.0, and AECOM wrote Sections 8.0 and 9.0. AECOM maintained the database, prepared Appendix A (Evaluation of Site I North), and prepared the data summary tables for Sections 3.0, 5.0, and 8.0. GSI Environmental, URS, Roux Associates, and Golder Associates prepared the figures. Each figure has the logo of the company that prepared it.

#### **1.4 Feasibility Study Purpose and Organization**

The Feasibility Study is presented in Sections 10.0 through 13.0 of this document. Section 10.0 includes a summary evaluation of Sauget Area 1 sites including those carried forward to the Feasibility Study that require remedial action as well as those sites that do not require active remedial action and are not carried forward. Section 10.0 also identifies the Remedial Action Objectives (RAOs) and the Applicable Relevant and Appropriate Requirement (ARARs) for Sauget Area 1 sites.

Section 11.0 identifies general response actions and identifies and screens remedial technologies that may be applicable to the Sauget Area 1 sites. Section 12.0 develops a range of potential remedial alternatives for Sauget Area 1 using the technologies and process options that were retained after the screening and evaluation completed in Section 11.0. Section 13.0 presents the detailed evaluation of five remedial action alternatives that were retained after the screening and evaluation in Section 12.0. GSI

Environmental was the primary author of the Feasibility Study and the associated figures, tables, and appendices.

## **2.0 SITE BACKGROUND**

### **2.1 Site Location and Description**

Sauget Area 1, which is located in the Villages of Sauget and Cahokia, St. Clair County, Illinois, consists of three closed waste disposal areas (Sites G, H and I), a closed construction debris disposal area (Site N), a backfilled impoundment (Site L), an inactive borrow pit (Site M) and Dead Creek, an actively-managed stormwater conveyance channel running through heavily-developed residential and commercial areas in its upper reaches and through agricultural and undeveloped areas in its lower reaches (Figures 1-2 and 1-4). Background information on each of these sites, previously reported in the Support Sampling Plan (SSP) using information from prior investigations (Solutia, 1999), is presented below along with a description of Dead Creek.

#### **2.1.1 Site G**

Site G is located in the Village of Sauget south of Queeny Avenue, west of Dead Creek and north of the containment cell constructed for the Sauget Area 1 Time-Critical Removal Action (Figure 1-3). The eastern portion of Site G is within a fenced area and is covered with vegetation. In previous reports, the disposal area boundary of Site G shown on site maps coincided with the fenced area, but this is not consistent with current information regarding the extent of waste and fill materials at Site G.

Waste and fill materials are not present within the southern portion of the fenced area but are present outside the fenced area to the west at the Wiese Engineering property. The Wiese property includes parking lots and a forklift maintenance building that is currently used for storage. This western portion of the disposal area is referred to as Site G West.

The disposal area at Site G and Site G West occupies approximately 3.3 acres. Site G and Site G West were operated and served as a disposal area from sometime after 1940 to 1966, and were subject to intermittent dumping thereafter until 1982, when most of the site was fenced pursuant to a USEPA removal action under CERCLA. Prior to the SSP investigation, there were estimated to be 60,000 cubic yards of wastes within Site G and Site G West, including oil pits located on the east side of Site G, buried drums containing wastes (including pyrophoric materials), paper wastes, documents and laboratory equipment.

Wastes located on the surface and/or in the subsurface within the fenced area of Site G spontaneously combusted and/or burned on four separate occasions during the period March to June 1994. USEPA conducted a second CERCLA removal action during the period March to September 1995. The on-scene coordinator's report summarized the results of this removal action (USEPA, 1995).

The 1995 removal action involved the following activities: soil sampling inside and outside the fenced area; excavation of approximately 25 cubic yards of soils along the Queeny Avenue sidewalk and 30-50 cubic yards of soils from the Wiese parking lot; placement of these soils within the fenced area; excavation of a waste pile on the southwest corner of the site and placement of these wastes within the fenced area; solidification of two oil pits located on the northeast and central east portions of the site; installation of a shallow barrier wall on the eastern boundary of the site; and installation of a clean soil



cover approximately 18-30 inches thick to cover the wastes inside the fenced area. The soil layer covered the entire fenced area except for the southeast and southwest corners and the central south portion of the fenced area (USEPA, 1995).

### **2.1.2 Site H**

Site H, which occupies approximately 4.9 acres of land, is located south of Queeny Avenue, west of Falling Spring Road and east of the Metro Construction Company property. The boundary between the Village of Sauget and the Village of Cahokia runs through Site H (Figure 1-3). Prior to the SSP investigation, the southern boundary of Site H was not known with certainty, but was estimated to extend approximately 1,250 feet south of Queeny Avenue. While Site H is not fenced and access is currently unrestricted, the property is graded and grass covered with exposed slag at grade.

Site H was at one time connected to Site I, but they are now separated at ground level by Queeny Avenue, which was constructed at its present location in 1949 or 1950. The landfill operated from approximately 1931 to 1957. Due to this physical connection, waste disposal at Site H was similar to that at Site I South. Industrial wastes were disposed here from approximately 1931 to 1957. Wastes included solvents, other organics and inorganics, including PCBs, para-nitroaniline, chlorine, phosphorous pentasulfide, and hydrofluosilic acid. Municipal wastes were also reportedly disposed at Site H. The estimated volume of waste in Site H prior to the SSP investigation was 110,000 cubic yards.

### **2.1.3 Sites I South and I North**

Site I occupies approximately 14.7 acres of land located north of Queeny Avenue, west of Falling Springs Road and south of the Alton & Southern Railroad in the Village of Sauget (Figure 1-3). Access to the site, which is fenced, graded, covered with crushed stone and used for equipment and truck parking, is restricted and controlled by Cerro Flow Products. Prior to performance of the SSP, Site I was estimated to contain approximately 250,000 cubic yards of contaminated wastes and fill material.

Cerro acquired the tracts constituting Site I in 1965 and 1967. Historically, Cerro periodically used inert fill material (e.g., refractory brick and construction debris) to fill low areas and maintain grades. Cerro continues to place clean, purchased stone and surplus concrete on the property to fill depressions.

Site I has been divided into two areas, Site I South and Site I North, based on further review of historical aerial photographs. The boundary between Site I South and Site I North is visible on historical aerial photographs from 1950, 1955, and 1962 (see Figures 2-28, 2-29, and 2-30). Sites I South and I North are described below and are considered as separate sites throughout the remainder of this report.

Site I South occupies approximately 8.8 acres of land and was at one time connected to Site H. Sites H and I South are separated at ground level by Queeny Avenue, which was constructed at its present location in 1949 or 1950. Sites H and I South together were known to be part of the "Sauget-Monsanto Landfill", which was originally used as a sand and gravel pit and then received industrial and municipal wastes from approximately 1931 to 1957. Cerro may also have used a part of Site I South to dispose of waste oil for a brief period of time during the late 1960s and early 1970s.

Wastes from Site I South potentially leached and/or were released into Creek Segment A and available downstream creek segments until Creek Segment A was remediated in 1990-1991. The Village of Sauget occasionally dredged Dead Creek and deposited the sediments from that dredging on the east bank of Dead Creek or Site I South.

In September 1989, several workers were sent to the hospital and one was kept overnight for observation after being exposed to materials brought to the surface during installation of a pole to carry computer lines. This incident occurred in Site I South at a location east of the railroad tracks and south of the main plant road.

Site I North occupies approximately 5.9 acres of land, and historical aerial photos indicate that this area was not part of the "Sauget-Monsanto Landfill" described above. As discussed in Section 3.2.2.3, the interior trench excavated at Site I North encountered bricks, concrete, rebar, sheet metal, wood, and soil.

#### **2.1.4 Site L**

Site L, located immediately east of Dead Creek and south of the Metro Construction Company property in the Village of Cahokia (Figure 1-3), was used for the disposal of wash water from truck cleaning operations from approximately 1971 to 1981. The trucks were used for bulk-chemical transport. Volume of contaminated fill material in the two closed impoundments that comprised Site L was not known prior to completion of the SSP investigation. However, the area of the impoundment was estimated to be 7,600 square feet. This site is now covered by cinders and used for equipment storage.

#### **2.1.5 Site M**

Site M, approximately 59,200 square feet in size and an estimated 14 feet deep, was located along the eastern side of Dead Creek at the western end of Walnut Street in the village of Cahokia (Figure 1-3). Originally used as a borrow pit in the middle to late 1940s, Site M was connected to Dead Creek through an opening at its southwest corner. In the past, water from Dead Creek entered Site M through this connection. An estimated 3,600 cubic yards of contaminated sediments was located in this borrow pit prior to the Removal Action. Contaminated sediments were removed from Site M in 2000/2001 under the Time-Critical Removal Action UAO and transferred to the Judith Lane containment cell (Figure 1-2). Site M was backfilled during sediment removal and a fence restricts access to the site.

#### **2.1.6 Site N**

Site N is located on property formerly owned by the H. Hall Construction Company on the eastern side of Dead Creek between Judith Lane and Cahokia Street in the Village of Cahokia (Figure 1-3). Initially developed as a borrow pit in the 1940s, this four-acre site was formerly used to dispose of concrete rubble, demolition debris, and to a lesser degree, some drums and other solid waste. Disposal of some painting wastes and/or chemical wastes may also have occurred at Site N based on observations during waste sampling and exploratory trenching performed at this site during the remedial investigations in 1999-2000 and 2003.

Currently inactive, access to the site is limited by a fence at the property line. Fill volume was not known prior to the SSP, but fill depth was estimated to be as much as 30 feet.

### 2.1.7 Dead Creek

Dead Creek is an approximately 17,000 ft. long, actively-managed stormwater conveyance channel running through heavily-developed residential and commercial areas in its upper reaches and through agricultural and undeveloped areas in its lower stretches before it discharges to Prairie du Pont Creek at the Metro East Sanitary District (MESD) lift station (Figure 1-4). Prairie du Pont Creek is located at the southern (downstream) end of Creek and routes all of the water from Dead Creek to the Mississippi River. When Sauget Area 1 was investigated by the Illinois Environmental Protection Agency (IEPA) in the 1980s (Ecology and Environment, 1988), Dead Creek was subdivided into six segments (Figure 1-4):

<u>Dead Creek Segments</u>	<u>Creek Segment Location</u>	<u>Creek Segment Length (Feet)</u>
• Creek Segment A	Alton & Southern Railroad to Queeny Avenue	1,800
• Creek Segment B	Queeny Avenue to Judith Lane	1,800
• Creek Segment C	Judith Lane to Cahokia Street	1,300
• Creek Segment D	Cahokia Street to Jerome Lane	1,100
• Creek Segment E	Jerome Lane to Route 157	4,300
• Creek Segment F	Route 157 to Prairie du Pont Creek	<u>6,500</u>
Estimated Total Length		16,800

Creek Segment A was remediated by Cerro Flow Products in 1990/1991 under a plan approved by IEPA. Approximately 27,500 tons of sediments were excavated and taken to Waste Management disposal facilities. Solutia remediated Creek Segments B, C, D, E and F by removing 46,000 cubic yards of sediments in 2001/2002 and 12,400 cubic yards of sediments and creek bottom soil in 2005/2006. Excavated sediments and soils removed after 2000 were transferred to a RCRA and TSCA-compliant on-site containment cell constructed adjacent to the west bank of Creek Segment B just north of Judith Lane (Figure 1-4).

## 2.2 Site Physical Characteristics

### 2.2.1 Climatology

Climate of the study area is described by the National Climatic Data Center (NCDC) as a modified continental climate. The area is subject to four-season climate changes without the undue hardship of prolonged periods of extreme heat or high humidity. To the south is the warm, moist air of the Gulf of Mexico; and to the north, in Canada, is a region of cold air masses. Convergence of air masses from these sources, and the conflict on the frontal zones where they come together, produce a variety of weather conditions, none of which are likely to persist for any great length of time.

Winters are brisk and seldom severe. Records since 1870 show that the temperature drops to zero degrees Fahrenheit (0°F) or below on average two to three days per year. The area stays at or below 32°F for less than 25 days in most years. Average snowfall for the area is a little over 18 inches per winter season. Snowfall of an inch or more is received on five to ten days in most years. Long-term

records for the St. Louis area (since 1870) indicate that temperatures of 90°F or higher occur on about 35 to 40 days per year, and extremely hot days of 100°F or more are expected no more than five days per year.

Normal annual precipitation for the area is slightly less than 34 inches. The winter months are the driest, with an average total of about six inches of precipitation. The spring months of March through May are normally the wettest with normal precipitation of just under 10.5 inches.

### **2.2.2 Hydrology**

Sauget Area 1 is situated in an area of the Mississippi River floodplain called the American Bottoms, which is located on the eastern side of the river directly opposite St. Louis, Missouri. American Bottoms encompasses approximately 175 square miles (30 miles north to south with a maximum width of 11 miles) and is bordered on the west by the Mississippi River and on the east by bluffs that rise 150 to 200 feet above the valley bottom. Land surface is relatively flat, ranging between 400 and 445 feet above mean sea level (MSL) and generally slopes from north to south and from east to west.

The Mississippi River, bordering the American Bottoms to the west, is the major surface-water body draining the area. It is fed by a complex network of natural and artificial channels that were extensively improved throughout the 20th Century. According to an investigation of groundwater resources conducted by the Illinois State Water Survey, at least 40 miles of improved drainage ditch were constructed in the American Bottoms and the natural lake area in the center of the floodplain was reduced by more than 40 percent.

Locally across Sauget Area 1 the topography consists of nearly flat bottomland with elevations ranging from 400 to 410 feet MSL. Dead Creek, a channelized stream, serves as the main conduit for surface-water drainage through Sauget Area 1. The creek flows to a floodway south of Cahokia (Prairie du Pont Creek), which in turn discharges to the Cahokia Chute of the Mississippi River. Surface drainage across the study area is generally toward Dead Creek, although localized drainage patterns are present at Sites G, H, I, L, M and N:

- An emergency response action by USEPA in 1995 resulted in the placement of a soil cover at Site G. Because of this, surface water flows radially away from the site.
- Drainage at Site H is typically toward Dead Creek, although the site is relatively flat and contains several depressions capable of retaining water. Water accumulating in these depressions due to precipitation infiltrates into the ash cinder cover or evaporates, rather than draining from the site across the surface.
- The majority of drainage at Site I South and Site I North is to the west although the grade is relatively flat. Water flows to an interceptor and is ultimately carried through a series of storm sewers and effluent pipes to the American Bottoms Regional Treatment Facility. Currently, stormwater runoff from Site I South drains to a catch basin on the north side of Queeny Avenue that drains into Creek Segment B. Water also infiltrates into the subsurface due to the flat grade and permeable stone parking areas, or evaporates.
- Drainage at Site L flows to the west toward Dead Creek across a cover of highly permeable material (cinders).

- Site M receives some runoff from a small residential area located on Walnut Street. Surface water discharges into Dead Creek on the west side of the former impoundment, which was backfilled during the Sauget Area 1 Time Critical Removal Action.
- Site N receives runoff from the surrounding area.

Ponding occurs in low-lying areas of Sauget Area 1 during periods of heavy precipitation because there is no stormwater drainage system to convey ponded water to Dead Creek. Stormwater periodically backs up in Dead Creek since MESD does not operate the lift station at Prairie du Pont Creek until the stormwater storage capacity of Dead Creek and the Borrow Pit Lake is fully utilized. The pumps come on at a pre-set level so that the stormwater does not cause overbank flooding. Overbank flooding from Dead Creek is very unlikely because a lift station controls discharge from the creek.

### **2.2.3 Geology**

The American Bottoms are underlain by unconsolidated valley fill composed of recent alluvium, known as the Cahokia Alluvium, which overlies a unit of glacial material known as the Henry Formation. Cahokia Alluvium is approximately 40 feet thick in the American Bottoms and consists of unconsolidated, poorly sorted, fine-grained material with some local sand and clay lenses. These alluvial deposits unconformably overlie the Henry Formation, which is composed of medium to coarse sand and gravel that increases in grain size with depth. This unit is approximately 95 feet thick and generally becomes thinner with increasing distance from the Mississippi River.

Sauget Area 1 is located in the southwestern section of the American Bottoms floodplain. More specifically, it is situated south of East St. Louis, and is approximately three-quarters to one mile east of the eastern bank of the Mississippi River. Stratigraphy beneath the Site is much like that of the rest of the floodplain. The Cahokia Alluvium is about 30 feet thick and exists as a fine-grained silty sand that is gray and brown in color with some interbedded silts and clays. Below this, the unconsolidated sand and gravel valley-fill deposits of the Henry Formation are present. Locally, the Henry Formation, which ranges in thickness from approximately 100 feet near the river to about 80 feet on the east side of the Site, is characterized by fine to medium sand in its upper portions and medium-to-coarse sand in its lower portions. Valley fill throughout the American Bottoms is underlain by Mississippian and Pennsylvanian bedrock consisting primarily of limestone and dolomite with some sandstone and shale units. In some locations, glacial till is encountered above bedrock and below the valley fill. Figure 2-1 presents a generalized geologic cross-section of the Site.

### **2.2.4 Hydrogeology**

Two types of water-bearing formations exist in the American Bottoms: unconsolidated and consolidated. Unconsolidated formations (clay, silt, sand and gravel) are those that lie between ground surface and bedrock. Thickness of the unconsolidated formation varies throughout the area, but is typically 100 to 110 feet thick in Sauget Area 1. Finer-grained sediments generally dominate at the ground surface and become coarser and more permeable with depth and, consequently, permeability and porosity increase with depth. Consolidated formations are deep bedrock units of limestone and dolomite that exhibit low permeability and are not considered to be a significant source for ground water in the area. As noted in

the literature, "... because of low permeability and poor water quality with depth, the bedrock does not constitute an important aquifer in the area" (Ritchey and Schicht, 1982). Further, Bruin and Smith (1953) state "The shallower consolidated rock formations in this area are generally not highly productive....". In some areas, till and/or boulder zones are encountered 10 to 15 feet above the bedrock surface.

Geologic data show that the thickness of the unconsolidated deposits ranges from approximately 140 feet at the Mississippi River in Sauget Area 2 to 100 feet in the eastern part of Sauget Area 1. At most locations, the contact between Cahokia Alluvium and the Henry Formation cannot be distinguished. However, three distinct hydrogeologic units can be identified at Sauget Area 1: 1) a Shallow Hydrogeologic Unit (SHU); 2) a Middle Hydrogeologic Unit (MHU); and 3) a Deep Hydrogeologic Unit (DHU).

The SHU includes the Cahokia Alluvium (recent deposits) and the uppermost portion of the Henry Formation. This unit, which is typically 30 ft. thick, is a fine-grained silty sand with silt and clay interbeds with low to moderate permeability. Typically 40 ft. thick, the MHU is formed by the upper to middle, medium to coarse sand portions of the Henry Formation. It contains a higher permeability sand than found in the overlying SHU, and these sands become coarser with depth. At the bottom of the aquifer is the DHU, which includes the high permeability, coarse-grained deposits of the lower Henry Formation. This zone is typically about 40 feet thick at the Site.

Regional hydraulic characteristics of the American Bottoms aquifer were determined by the Illinois State Water Survey using information from 10 aquifer tests and 100 specific-capacity tests conducted on industrial, municipal, irrigation and relief wells (Ritchey and Schicht, 1982). Hydraulic conductivity values for the aquifer ranged from  $1.0 \times 10^3$  to  $3.0 \times 10^3$  gallons per day per square foot ( $4.7 \times 10^{-2}$  to  $1.4 \times 10^{-1}$  centimeters per second). Coefficient of storage ranged from 0.002 to 0.155.

Hydraulic properties of the three hydrogeologic units in the vicinity of Sauget Area 1, which are summarized below, were determined using data that Ritchey and Schicht (1982) obtained from aquifer tests performed over a span of 30 years:

**Average Hydraulic Characteristics of the Shallow, Middle and Deep Hydrogeologic Units at Sauget Area 1**

<u>Hydrogeologic Unit</u>	<u>Transmissivity</u> (gpd/ft)	<u>Hydraulic Conductivity</u> (gpd/ft <sup>2</sup> ) (cm/sec)		<u>Storage Coefficient</u>
Shallow Hydrogeologic Unit	141.5	9.5	$4 \times 10^{-4}$	Not Available
Middle Hydrogeologic Unit	165,000	3,300	$1.6 \times 10^{-1}$	0.04
Deep Hydrogeologic Unit	211,000	2,600	$1.2 \times 10^{-1}$	0.002 to 0.1

Slug tests were performed for the Support Sampling Plan to determine the hydraulic coefficients for the aquifer system at Sauget Area 1. To conduct the slug tests, three two-inch diameter, stainless steel piezometers were installed adjacent to each disposal area (Sites G, H, I, L, and N). The three wells in each area were screened in the SHU, MHU and DHU. Fifteen slug tests were performed (five tests in each of the three zones). Data collected during these tests were recorded with a Hermit Data logger and then analyzed using the Bouwer-Rice method for unconfined aquifers. Slug test locations are shown on Figure 2-2, identified with the prefix "ST" and the results from these tests are summarized below:

SHU, MHU and DHU Hydraulic Conductivity Estimates Based on Sauget Area 1 Support Sampling Plan Slug Test Data

<u>Hydrogeologic Unit</u>	<u>Hydraulic Conductivity (centimeters per second)</u>					<u>Average</u>
	<u>Site G</u>	<u>Site H</u>	<u>Site I</u>	<u>Site L</u>	<u>Site N</u>	
Shallow Hydrogeologic Unit	6.24E-3	4.32E-3	4.53E-3	2.44E-3	2.71E-2	8.93E-3
Middle Hydrogeologic Unit	3.47E-2	2.14E-2	5.07E-2	4.76E-2	2.20E-2	3.53E-2
Deep Hydrogeologic Unit	3.31E-2	1.84E-2	1.27E-1	2.52E-2	1.37E-2	4.35E-2

Analysis of the slug test data indicated that the hydraulic conductivity for the SHU ranged from  $2.44 \times 10^{-3}$  to  $2.71 \times 10^{-2}$  cm/s for the SHU,  $2.14 \times 10^{-2}$  to  $5.07 \times 10^{-2}$  cm/s for the MHU, and  $1.37 \times 10^{-2}$  to  $1.27 \times 10^{-1}$  cm/s for the DHU. Average hydraulic conductivity in the SHU, MHU and DHU was  $8.93 \times 10^{-3}$ ,  $3.53 \times 10^{-2}$  and  $4.35 \times 10^{-2}$  cm/sec, respectively, and increased downward from the SHU to the MHU and then the DHU. For a description of the procedures that were followed during the aquifer testing program and for supporting documentation, refer to Section 3.14 of the FSR (Volume 3).

Aquifer characteristics used throughout this document were selected after considering historical regional sustained pumping data, together with the site-specific data that were collected as a part of the SSP. These aquifer characteristics are listed below:

<u>ALLUVIAL AQUIFER CHARACTERISTICS</u>				
<u>Ground Water Unit</u>	<u>Saturated Thickness (feet)</u>	<u>Average Hydraulic Conductivity (gal/day-ft<sup>2</sup>)</u>	<u>Average Hydraulic Conductivity (cm/sec)</u>	<u>Hydraulic Gradient (ft/ft)</u>
Shallow Hydrogeologic Unit	15	212.1	$1 \times 10^{-2}$ cm/s	.001
Middle Hydrogeologic Unit	40	2121	$1 \times 10^{-1}$ cm/s	.001
Deep Hydrogeologic Unit	40	2121	$1 \times 10^{-1}$ cm/s	.001

Recharge to the American Bottoms aquifer occurs through four sources: precipitation, infiltration from the Mississippi River, inflow from the buried-valley channel of the Mississippi River and subsurface flow from the bluffs that border the floodplain on the east.

Groundwater beneath Sauget Area 1 flows generally from east to west, toward the Mississippi river with horizontal groundwater gradients averaging about 0.001 feet per foot (ft/ft) to the west. (During high river stage, gradients near the river reverse because surface water levels in the Mississippi River are higher than groundwater levels in the American Bottoms aquifer.) Downward vertical gradients occur on parts of the Site, with varying magnitudes depending on location and season.

Groundwater flow direction in Sauget Area 1 during implementation of the Support Sampling Plan was determined by installing nine piezometer clusters and measuring groundwater levels in each cluster quarterly for four quarters. Each cluster contained three small-diameter piezometers screened in the SHU (0-30 feet deep), MHU (30-70 feet deep), and DHU (greater than 70 feet deep). SHU, MHU and DHU groundwater elevation contour maps were prepared for the third and fourth quarters of 1999 (3Q99 and 4Q99) and the first and second quarters of 2000 (1Q00 and 2Q00). Groundwater level contours for

3Q99, 4Q99, 1Q00 and 2Q00 are shown on Figures 2-3 to 2-6 for the SHU, Figures 2-7 to 2-10 for the MHU and Figures 2-11 to 2-14 for the DHU. Groundwater flow direction in the SHU, MHU and DHU is to the west and northwest at an approximate gradient of one foot vertical to 1,000 feet horizontal (0.001 ft/ft). Estimated groundwater flow velocity is 29.6 feet per year in the SHU and 296 feet per year in the MHU/DHU based on a porosity of 0.35.

Groundwater-level measurements indicate downward vertical gradients occurred in portions of Sauget Area 1 during performance of the SSP. Vertical groundwater-level measurements in piezometer cluster P2-C-Shallow (S), Middle (M) and Deep (D), which is the closest cluster to the Sauget Area 1 disposal areas, are presented below:

**SHU/MHU and MHU/DHU Head Differences in 3Q99, 4Q99, 1Q00 and 2Q00 at Piezometer Cluster P2-C-S, M and D**

Groundwater Level Piezometer	3Q99		4Q99		1Q00		2Q00	
	<u>GWL</u>	<u>Head</u>	<u>GWL</u>	<u>Head</u>	<u>GWL</u>	<u>Head</u>	<u>GWL</u>	<u>Head</u>
P2-C-S	399.00	NA	397.83	NA	396.58	NA	401.81	NA
P2-C-M	398.80	0.20 ▼	395.61	2.22 ▼	394.14	2.44 ▼	395.20	6.61 ▼
P2-C-D	398.30	0.50 ▼	395.62	0.01 ▲	394.17	0.03 ▲	395.23	0.03 ▲

Notes: 1) GWL = Groundwater Level Elevation, Feet NGVD  
 2) Head = Head difference between SHU and MHU and MHU and DHU  
 3) ▼ = Downward Head (GWL in upper unit higher than in lower unit)  
 4) ▲ = Upward Head (GWL in lower unit higher than in upper unit)

Head differences (gradients) between the SHU and MHU were downward in all four quarters but the magnitude of the head difference varied widely, from 0.20 feet in 3Q99 to 6.61 feet in 2Q00. In all but 3Q99, head differences between the MHU and DHU were upward although the magnitude was small, ranging from 0.01 to 0.03 feet. In 3Q99 there was a 0.50 ft. downward head difference between the MHU and the DHU.

An upward vertical gradient is expected as groundwater in the alluvial aquifer system approaches and discharges into the Mississippi River, which is a gaining stream in the region and serves as the discharge boundary for the American Bottoms alluvial aquifer system.

Historically, groundwater from the American Bottoms aquifer was a major source of water for the area and was used for industrial, cooling water, and irrigation purposes. Groundwater levels prior to industrial and urban development were near land surface. Intensive industrial withdrawal and use and construction of a system of drainage ditches, levees, and canals to protect developed areas lowered groundwater levels for many years. However, by the mid-1980s, groundwater levels increased due to reduced pumpage, high river stages, and high precipitation.

Currently, no groundwater is being pumped from the American Bottoms aquifer within or in the vicinity of Sauget Area 1 for public or industrial supply purposes. The Villages of Cahokia and Sauget both have city ordinances that prohibit use of groundwater as potable water and the public water supply is the exclusive potable water source. Nine individual residential wells (see Figure 2-27) were identified within Sauget Area 1: 101 Walnut Street, 3300 Falling Springs Road, 100 Judith Lane, 102 Judith Lane, 104



Judith Lane, 109 Judith Lane, 118 Edwards Street, 22 Cahokia Street, and 24 Cahokia Street (Ecology and Environment, 1998 and Solutia, 1999). These wells are used for irrigation purposes and four of them were sampled as part of the SSP investigation.

Drinking water for area residents comes from the Illinois American Water Company (IAWC) surface water intake in the Mississippi River located at river mile 181, approximately three miles north of Sauget Area 1 and about six miles upstream of the confluence of Dead Creek with Prairie du Pont Creek. IAWC supplies water to Sauget and the Commonfields of Cahokia Public Water District, which distributes water to portions of Cahokia and Centerville Township. The Cahokia Water Department also purchases water from IAWC and distributes it to small residential areas in the west and southwest portions of Cahokia.

The nearest downstream surface-water intake on the Illinois side of the Mississippi River is located at river mile 110, approximately 64 miles south of Sauget Area 1. This intake supplies drinking water to residents in the Town of Chester and surrounding areas in Randolph County, Illinois. A Ranney well operated by the Village of Crystal City, Missouri (pop. 4,000) at river mile 149, approximately 28 miles downstream of Dead Creek, is the nearest public water supply on the Missouri side of the river.

Agricultural land in Sauget Area I is not irrigated.

### **2.2.5 Demography and Land Use**

Sauget Area 1 is located in the Villages of Sauget and Cahokia and the City of East St. Louis is located approximately a half mile north of the Site. Residential populations of these area municipalities as of the latest census are, respectively, about 200; 17,550 and 40,944. Small residential, commercial and agricultural properties are interspersed throughout the Village of Sauget. There is a residential area adjacent to Sites H and I with the closest residence approximately 200 feet to the east. The Sauget Village Hall is located on Site I but not necessarily on waste. Vacant land is located in a number of areas in Sauget including just south of Site L, east of Falling Springs Road and west of Route 3.

Heavy industry has been located on the east bank of the Mississippi River between Cahokia and Alton, Illinois (also known as the "American Bottoms") for over a century. Although much of the industry has closed down throughout the American Bottoms, the primary land use in the vicinity of Sauget Area 1 continues to be industrial, with over 50 percent of the land being used for this purpose. In addition to heavy industry (chemical plants, copper tube manufacturing, zinc processing/recycling plants, a foundry, a hazardous waste incinerator, an ethanol production plant), the Sauget and Cahokia area currently is also home to warehouses, trucking and barge terminal facilities, underground pipelines, commercial facilities, and miscellaneous business establishments.

Closed and currently operating commercial and industrial facilities located in or near Sauget Area 1 are listed below:

<u>Facility</u>	<u>Years of Use</u>	<u>Use</u>
<b>Cahokia Marine Services &amp; Slay Terminals</b>	<b>1979 to date</b>	<b>Coal Bulk Storage and Transfer</b>
<b>Center Ethanol</b>	<b>2008 to date</b>	<b>Ethanol processing</b>
<b>Cerro Flow Products</b>	<b>1927 to date</b>	<b>Current - Copper Tube Manufacturing</b>

		<b>Historic - Copper Recycling and Cathode Production</b>
<b>Clayton/RRG</b>	<b>1962-1998</b>	<b>Waste Recycling</b>
<b>Chemical Warfare Service</b>	<b>1942 to 1945</b>	<b>Chemicals for the war effort</b>
<b>Darling Fertilizer</b>	<b>1921 to 1967</b>	<b>Chemical Fertilizer</b>
<b>Eagle Marine Industries</b>	<b>1962 to date</b>	<b>Barge Terminal and Fleeting</b>
<b>Ethyl Petroleum Additives (f/k/a Edwin Cooper, n/k/a Afton Chemical Corp.)</b>	<b>1971 to date</b>	<b>Petroleum Additive Manufacturing</b>
<b>Illinois Central (f/k/a Gulf, Mobil &amp; Ohio Railroad)</b>	<b>1930 to 1959</b>	<b>Railroad yard and roundhouse facility</b>
<b>Mobil (n/k/a ExxonMobil)</b>	<b>1917 to 1993</b>	<b>Refinery &amp; Tank Farm</b>
<b>Midwest Rubber</b>	<b>1928 to 1997</b>	<b>Rubber Recycling</b>
<b>Pillsbury</b>	<b>1979 to 1989</b>	<b>Bulk Grain Storage and Transfer</b>
<b>Phillips Petroleum (n/k/a ConocoPhillips)</b>	<b>1931 to date</b>	<b>Petroleum Bulk Storage and Transfer</b>
<b>Peavey/ConAgra</b>	<b>1989 to date</b>	<b>Bulk Grain Storage and Transfer</b>
<b>Rogers Cartage</b>	<b>1970 to 1990</b>	<b>Truck terminal/truck washing</b>
<b>River City Landscape Supply</b>	<b>1993 to date</b>	<b>Lawn and Garden Product Storage</b>
<b>T.J. Moss</b>	<b>1927 to 1969</b>	<b>Wood Treating</b>
<b>Sterling Steel Castings</b>	<b>1922 to date</b>	<b>Foundry</b>
<b>Union Electric (n/k/a Ameren)</b>	<b>1923 to 1979</b>	<b>Power generation and electricity distribution</b>
<b>Veolia Environmental Services (f/k/a Trade Waste Incineration)</b>	<b>1979 to date</b>	<b>Hazardous Waste Incinerator</b>
<b>W.G. Krummrich Plant (past and present owners include Pharmacia and Solutia)</b>	<b>1917 to date</b>	<b>Chemical manufacturer</b>
<b>Waggoner Trucking</b>		<b>Truck terminal/truck washing</b>
<b>Wiese Engineering</b>	<b>1967 to date</b>	<b>Equipment repair</b>
<b>Zinc Plant (American Zinc, Cyprus Amax, Big River Zinc are all past owners)</b>	<b>1940 to date</b>	<b>Historic - Zinc roast and processing. Current - In conversion to a zinc recycling facility.</b>

Prior to the late 1950's, waste disposal for local residents, industries and businesses took place in large part in landfills located in Sauget Area 1 (Sites G, H and I). After the late 1950's, similar types of wastes were disposed of in landfills that are today part of the Sauget Area 2 Superfund sites, located adjacent to (and down gradient of) Sauget Area 1. Wastes likely disposed of in the Sauget Area 1 landfills include:

**Filter Cake/Aid  
Waste Solvent  
Sludges  
Construction Debris  
Refractory Brick**

**Pine Tars  
Wood Treatment Chemicals  
Waste Paper  
Paper Sacks  
Foundry Sand**

**Fiber Packs  
Steel Drums  
Waste Catalyst  
Truck Tank Washings  
Misc. Chemical Production Wastes**

**Slag  
Still Bottoms  
Municipal Waste  
Lab Wastes**

Before 1930, industries, and other facilities located along the Dead Creek, disposed of wastewater directly into the Creek. As industry grew, use of the creek for waste disposal declined. Sometime in the 1930's the portion of Dead Creek located on the W.G. Krummrich plant property was backfilled. In the early to mid 1930's Village of Sauget installed sewers that carried sanitary and industrial/commercial wastewaters to the Mississippi River. The Village sewer system consisted of a north trunk running along Monsanto Avenue and a 24-inch diameter south trunk, running just south of the W.G. Krummrich plant, which conveyed sewage from east to west toward the river. The sewer system also included an 18-inch sewer line that flowed from Route 3 eastward into Dead Creek. Sometime between 1939 and 1943, the Village incorporated Dead Creek to act as surge pond in the Village sewer system in order to relieve the sewers in times of high storm water volume flows. Thus, Dead Creek received wastewater discharges from various Sauget industries and residences until the sewer connection to the Creek was closed in 1990. In addition, after 1933, some individual sewer outfalls continued to discharge wastewater directly into Dead Creek.

At some point the Village of Sauget dredged Dead Creek between the W.G. Krummrich plant and Queeny Ave. Dredged material was deposited along the east bank of the creek or at Site I South. Such dredging may have occurred more than one time.

Trucking companies that hauled a wide variety of chemical products for various industries began to wash tank trucks in Sauget Area 1 beginning in the mid-1960s. Wash water was discharged directly into Dead Creek, the north trunk of the Sauget sewer, and into pits at Site L. Wash water discharges directly into Dead Creek were discontinued in about 1971. Discharges into Site L were discontinued sometime in the late 1970's. Discharges to the sewer from truck washing operations continued until at least the overflow at the north end of Dead Creek was closed in 1990.

Because of the wide variety of facilities that have been located in Sauget over the years, the Sauget Area 1 landfills and Dead Creek received a broad array of waste materials including solvents, chemical precursors and intermediates, petroleum hydrocarbons, aromatic amines, halogenated aromatic hydrocarbons, PAHs, PCBs, herbicides, pesticides acids, metals, and lubricating oil additives.

## **2.3 Sauget Area 1 Removal and Remedial Actions**

### **2.3.1 Source Areas**

#### **2.3.1.1 Site G Removal Action**

USEPA conducted a CERCLA removal action at Site G in 1995. This removal action involved the following activities: soil sampling inside and outside the fenced area; excavation of approximately 25 cubic yards of soils along the Queeny Avenue sidewalk and 30-50 cubic yards of soils from the Wiese parking lot; placement of these soils within the fenced area; excavation of a waste pile on the southwest corner of the site and placement of these wastes within the fenced area; solidification of two oil pits located on the northeast and central east portions of the site; installation of a shallow barrier wall on the eastern boundary of the site; and installation of a clean soil cover approximately 18-30 inches thick to cover the wastes inside the fenced area. The soil layer covered the entire fenced area except for the southeast and southwest corners and the central south portion of the fenced area (USEPA, 1995).

### **2.3.2 Dead Creek**

#### **2.3.2.1 Creek Segment A Sediment Remedial Action**

This northernmost segment of Dead Creek originally consisted of two holding ponds that the Village of Sauget occasionally dredged. Sediments from that dredging were deposited on the east bank of Dead Creek or at Site I South.

Cerro Flow Products conducted a remedial action in Creek Segment A during 1990 and 1991 under an IEPA-approved plan. Approximately 27,500 tons of contaminated sediments were excavated from depths of 10 to 15 feet below grade and transported to separate non-hazardous, RCRA and TSCA permitted Waste Management disposal facilities, depending upon the nature of the excavated materials. After installation of an HDPE vapor barrier, Creek Segment A was backfilled and covered with crushed gravel.

Since Creek Segment A was remediated under an agreement with the IEPA, no additional remedial or removal actions are planned for this stretch of Dead Creek. Total cost for this remedial action was approximately \$14M.

#### **2.3.2.2 Creek Segment B, C, D, E and F Sediment Removal Action**

USEPA issued a UAO on June 21, 1999 for a Time Critical Removal Action requiring replacement of Dead Creek culverts (USEPA, 1999b). Solutia and USEPA reached agreement that the UAO would be limited to the culverts at Cargill Road and the Terminal Railroad Embankment (Figure 1-4) and replacement of these culverts was completed in 2000 at a cost of approximately \$750,000.

On May 31, 2000, USEPA modified the June 21, 1999 UAO to include removal of sediments in Creek Segment B, C, D and E in order to eliminate potential risks associated with flooding and to eliminate adverse ecological impacts (Figure 1-4). On August 29, 2001, the UAO was amended to include sediments in CS-F between Route 157 (Camp Jackson Road) and the confluence of Dead Creek with the Borrow Pit Lake. Sediments in the MESD lift station sump at Prairie du Pont Creek were included in the sediment removal action.

Solutia submitted a Time Critical Removal Action Work Plan to USEPA on June 30, 2000 and the plan was approved in April 2001. Work began in November 2000 with the installation of a sediment dewatering system in Dead Creek. Pursuant to USEPA's acceptance of the work plan and associated designs, a 50,000 cubic yard, RCRA and TSCA compliant, on-site containment cell was constructed in 2001 adjacent to the west bank of Creek Segment B immediately south of Site G and north of Judith Lane (Figure 1-4). USEPA approved sediment transfer to the completed containment cell in September 2001. Sediment transfer to the cell began shortly thereafter and excavation and transfer of all sediments in Creek Segments B, C, D and E and the channel portion of Creek Segment F to the containment cell was completed in February 2002. Solutia excavated a total of 46,000 cubic yards of sediments. The sediments were soft, unconsolidated materials, and they had much lower shear strength than the underlying natural creek bottom soils. No sediments remained in Creek Segments B, C, D, E, and F after completion of the sediment removal action in 2001-2002, thereby eliminating any potential adverse ecological impacts associated with sediments that were present prior to that time.

By agreement with USEPA, risk-based concentrations (RBCs) for protection of forage fish in Dead Creek were developed for residual concentrations of known bioaccumulative compounds (Total DDT, Dieldrin, gamma-Chlordane, Total PCBs, Dioxin TEQ and Mercury), and site-specific metals (Copper, Lead and Zinc), and Bis(2-ethylhexyl)phthalate. Following the sediment removal efforts within Creek Segments B, C, D, E and F in 2001-2002, the remaining creek bottom soils were sampled and compared against the RBCs.

#### **2.3.2.3 Creek Segment B, D and F Soil Removal Action**

By agreement with USEPA, risk-based concentrations (RBCs) for protection of forage fish in Dead Creek were developed for residual concentrations of known bioaccumulative compounds (Total DDT, Dieldrin, gamma-Chlordane, Total PCBs, Dioxin TEQ and Mercury), site-specific metals (Copper, Lead and Zinc),

and Bis(2-ethylhexyl)phthalate. Following the sediment removal efforts within Creek Segments B, C, D, E and F in 2001-2002, the remaining creek bottom soils were sampled and compared against the RBCs.

Creek bottom soil samples were collected on sampling transects located at approximately 100 ft. intervals in Creek Segment B, 150-ft. intervals in Creek Segments C, D and E and 400-ft. intervals in Creek Segment F (Figures 2-15, 2-16, 2-17, 2-18 and 2-19). Creek bottom soil samples were analyzed for VOCs, SVOCs, Pesticides, Herbicides, PCBs, Dioxin and Metals (Solutia, 2008b). Sampling started in October 2001 and was completed in February 2002. Sample analysis and data validation were completed in May 2002.

Site-specific, risk-based concentrations (RBCs) for the protection of forage fish were exceeded in creek bottom soil at the following sampling transects (Figures 2-15, 2-16, 2-17, 2-18 and 2-19):

**Creek Bottom Soil Sampling Locations with Concentrations Greater than Site-Specific, Risk-Based Concentrations**

<b>Creek Segment</b>	<b>Constituent</b>	<b>Transect</b>
<b>Creek Segment B</b>	<b>Bis(2-ethylhexyl)phthalate</b>	<b>T3</b>
	<b>Total PCBs</b>	<b>T0, T1, T3, T5, T6, T8, T11 and T17</b>
	<b>Dioxin TEQ</b>	<b>T0, T3, T16 and T17</b>
	<b>Mercury</b>	<b>T0, T1, T2, T3, T6, T9, T11, T12 and T17</b>
	<b>Zinc</b>	<b>T0, T4, T8, T11 and T12</b>
<b>Creek Segment C</b>	<b>Mercury</b>	<b>T6</b>
<b>Creek Segment D</b>	<b>Total PCBs</b>	<b>T6</b>
	<b>Dioxin TEQ</b>	<b>T6</b>
	<b>Mercury</b>	<b>T4</b>
	<b>Zinc</b>	<b>T1 and T2</b>
<b>Creek Segment E</b>	<b>Mercury</b>	<b>T2, T6, T8, T9, T10, T11, T12, T13, T14, T15, T16 and T17</b>
	<b>Zinc</b>	<b>T16</b>
<b>Creek Segment F</b>	<b>Dioxin TEQ</b>	<b>T5</b>
	<b>Mercury</b>	<b>T3, T5, T9 and T14</b>
	<b>Zinc</b>	<b>T5</b>

On November 2, 2005, USEPA approved the October 28, 2005 "Sauget Area 1 Time Critical Sediment Removal Action, Revised Creek Bottom Soil Removal Work Plan, Creek Segments B, D and F" for excavation of creek bottom soils with residual concentrations greater than RBCs. Mercury removal was not considered necessary in Creek Segments C, D and E because public-health protection measures (dewatering to control mosquitoes) resulted in a habitat that was not conducive to a sustainable fish population.

A second work plan, "Sauget Area 1 Time Critical Sediment Removal Action, Soil and Sediment Removal Work Plan, Dead Creek Segment F and Borrow Pit Lake", was submitted to USEPA on December 8, 2005. USEPA approved the work plan on December 21, 2005.

**Creek Segment B** - RBCs were exceeded at Creek Segment B Transects T0, T1, T2, T3, T4, T5, T6, T8, T9, T11, T12, T16 and T17. Excavation was conducted at the following locations and depths in order to remove these creek bottom soils:

**Summary of Creek Bottom Soil Excavation Locations and Depths in Creek Segment B**

<u>Excavation Location</u>		<u>Excavation Depth</u>
<u>Start</u>	<u>Finish</u>	<u>(Feet)</u>
T0+00	T1+12.5	3.6
T1+87.5	T2+37.5	2.4
T2+37.5	T3+37.5	6.2
T4+87.5	T5+12.5	1.8
T5+87.5	T6+62.5	1.5
T7+87.5	T8+12.5	1.6
T8+87.5	T9+12.5	1.9
T10+87.5	T11+12.5	1.7
T11+87.5	T12+12.5	1.6
T15+50	T16+50	1.7
T16+87.5	T17+37.5	1.7

Excavation started at Queeny Avenue and worked to downstream to the Judith Lane. A total of 2,300 cubic yards of soil was removed between December 6 and 22, 2005. Confirmation soil sampling was performed to ensure the excavated areas no longer contained concentrations of constituents that exceeded their respective RBCs. Confirmation soil samples, collected at a depth of one foot below the base of each excavated area, demonstrated that concentrations of Total PCBs, Bis(2-ethylhexyl)phthalate, Mercury, Zinc, and Dioxin TEQ were below RBCs throughout the entire length of Creek Segment B (Solutia, 2008b). Creek bottom soil sampling transects remaining in Creek Segment B after completion of these excavations are shown on Figure 2-20.

**Creek Segment D** - After completion of sediment removal in Creek Segment D, creek bottom soils at sampling transects T1 and T2 had residual zinc concentrations greater than the 4,379 mg/kg RBC. Excavation of these soils was completed on January 11, 2006 after a total of 840.5 cubic yards of creek bottom soil was removed to an average depth of 1.6 ft. between T0+00 and T3+15. Excavated soil was transferred to the Judith Lane containment cell. Post-excavation soil sampling demonstrated that residual zinc concentrations in the excavation area were below the RBC (Solutia, 2008b).

Creek bottom soils in the southern portion of Creek Segment D (Sampling Transect T6), just upstream of Jerome Lane, contained residual concentrations of Total PCBs and Dioxin TEQ that exceeded their respective RBCs of 0.58 and 0.00051 mg/kg after completion of sediment removal. Excavation to an average depth of 1.3 ft. between stations T5+00 and T6+50 was completed on January 18, 2006. A total of 282.5 cubic yards of creek bottom soil was transferred to the Judith Lane containment cell. An additional 77 cubic yards was removed to cleanup cross contamination resulting from transfer soil from the excavation area at the south end of Creek Segment D to the truck loading area on the south side of Kinder Street. Post-excavation confirmatory sampling demonstrated that Total PCB concentrations were below the RBC of 0.58 mg/kg but the Dioxin TEQ RBC of 0.00051 mg/kg was exceeded at transect T5. An additional 180 cubic yards of material was excavated between CSD-T5 and CSD-T5+50 on March 8, 2006.

Creek bottom soil sampling transects remaining in Creek Segments C, D and E after completion of these excavations are shown on Figures 2-21, 2-22 and 2-23.

**Creek Segment F** - Dioxin TEQ and Zinc were detected in creek bottom soils at a concentration higher than their respective RBCs of 0.00051 mg/kg and 4,739 mg/kg at Sampling Transect T5 in Creek Segment F after completion of sediment removal in 2002. Mercury was also detected at concentrations higher than the 0.18 mg/kg RBC in creek bottom soils at sampling transects T3, T5, T9 and T14. Beta-BHC was present in creek bottom soils at transect T3 with a concentration greater than the 0.00222 mg/kg site-specific, soil to groundwater leaching criterion.

Excavation of creek bottom soils at sampling transects T3, T5, T9 and T14 started on January 25, 2006 and was completed on February 16, 2006. Approximately 1,328 cubic yards of wet soil were removed from Creek Segment F at the following excavation locations, mixed with a drying/solidifying agent ("Code L") and then transferred to the Judith Lane containment cell:

**Summary of Creek Bottom Soil Excavation Locations, Depths and Targeted Constituents in Creek Segment F**

<u>Excavation Location</u>		<u>Excavation Depth (Feet)</u>	<u>Targeted Constituents</u>
<u>Start</u>	<u>Finish</u>		
T2+200	T3+200	1.1	beta-BHC and Mercury
T4+200	T5+200	1.2	Dioxin TEQ, Mercury and Zinc
T8+200	T9+200	0.8	Mercury
T13+200	T15+00	1.0	Mercury

Confirmatory sampling in the bottom of the excavated areas demonstrated that residual concentrations of beta-BHC, Dioxin TEQ, Mercury and Zinc were below RBCs (Solutia, 2008). Creek bottom soil sampling transects remaining in Creek Segment F after completion of these excavations are shown on Figure 2-24.

#### **2.3.2.4 Borrow Pit Lake Soil Removal Action**

In May 2003, surface and subsurface sediment samples were collected from the Borrow Pit Lake to characterize the extent of Mercury concentrations greater than the 0.18 mg/kg RBC. Samples were collected from the center point of 60 grid cells; cells north of the confluence of Dead Creek were 300 ft. by 300 ft. in size and cells south of the confluence were 200 ft. by 200 ft. (Figure 2.25). Surface sediment samples (0 to 6 inches) were collected from all 60 grid cells while subsurface sediment samples (6 to 18 inches) were collected from odd numbered cells. Mercury concentrations exceeded the RBC in Grid Cells 30, 31, 32, 33, 34, 36, 38, 49 and 50 (Solutia, 2008b).

Excavation of sediments from these grid cells was initiated on January 31, 2006 and completed on February 22, 2006. Grid Cells 30, 31, 32, 33, 34, 36 and 49 were excavated to an average depth of 0.6 ft. below ground surface while Grid Cells 38 and 50 were excavated to an average depth of 1.3 ft. and 0.9 ft. below ground surface, respectively. A total of 6,500 cubic yards of sediment were removed and transferred to the Judith Lane containment cell during this time period. Excavation of an additional 761 cubic yards of sediment was done in Grid Cells 38 and 49 between February 24 and 28, 2006 in order to achieve the RBC. The access ramp into Grid Cell 49 was removed in two steps; excavation of 40 cubic yards on March 7, 2006 and 14 cubic yards on March 24, 2006. In total, 7,315 cubic yards of sediment were excavated from the Borrow Pit Lake and transferred to the Judith Lane containment cell.

Confirmatory samples collected from the excavation areas demonstrated that residual concentrations of mercury were less than the site-specific, risk-based concentration of 0.18 mg/kg (Solutia, 2008b).

### 2.3.2.5 Creek Segment E Soil Removal Action

Creek bottom soil sampling after sediment removal revealed that Dieldrin concentrations at sampling transect T16 exceeded the 0.0153 mg/kg TACO Tier II site-specific criterion established for soil to groundwater leaching in Creek Segment E (Figure 2.18). In addition, Zinc concentrations exceeded the 4,379 mg/kg RBC. Removal of creek bottom soils at Creek Segment E Transect 16 was approved by USEPA on February 23, 2006 so that the residual concentration of Dieldrin in excess of the 0.0153 mg/kg site-specific TACO Tier II criteria for soil to groundwater leaching at this sampling location could be transferred to the Judith Lane containment cell.

Between October 31 and November 1, 2006, approximately 20 cubic yards of wet soil were excavated to a depth of 0.75 ft from 15 feet upstream to 15 feet downstream of T16 in order to remove Dieldrin concentrations above the soil to groundwater leaching criterion. Ground corncobs, a drying agent, were mixed with the excavated soils prior to transporting the excavated material to Waste Management's Milam Landfill in East St. Louis, Illinois. Confirmation sampling at 13 locations in the bottom of the excavation area (Solutia, 2008b) demonstrated that Dieldrin concentrations were non-detect at all locations with detection limits ranging from 0.00035 mg/kg to 0.00042 mg/kg. Given the complete removal of residual concentrations of Dieldrin from this excavation area, it is reasonable to assume that residual Zinc concentrations higher than the RBC were also removed.

### 2.3.2.6 Creek Segment B Liner

The Time-Critical Removal Action UAO requires installation of an armored, impermeable liner throughout the entire length of Creek Segment B. Approximately 1500 ft. of liner with the following section were installed in 2007 before the on-set of cold, wet weather prevented completion of the last 300 ft. upstream of Judith Lane.

#### Creek Segment B Armored Channel Liner Section

Top of Liner Section	Riprap Protective Layer Geotextile	3 to 6-Inch Crushed Limestone Dense Grade Bedding Material Non-Woven Cushion Layer
Bottom of Liner Section	Membrane Liner Geotextile	60 mil HDPE Non-Woven Cushion Layer

Unusually wet weather in 2008 delayed resumption of liner installation until November but construction was completed by year end 2008.

## 2.4 Sauget Area 2 Groundwater Migration Control System

On October 3, 2002, an Administrative Order for Remedial Design and Interim Remedial Action associated with the Sauget Area 2 groundwater operable unit (OU) was sent by USEPA to a list of PRPs for the Sauget Area 2 Superfund Site. The Order (Docket No. V-W-02-C-716) directed respondents to perform a remedial design for the Interim Groundwater Remedy, as described in the associated



Statement of Work (SOW) and the ROD dated September 30, 2002, and to implement the design by performing an interim remedial action. The Sauget Area 2 Groundwater Migration Control System (GMCS) was designed to abate adverse impacts on the Mississippi River resulting from the discharge of groundwater from Sauget Area 2 Sites O, Q North, R and S; potential adverse impacts from Sauget Area 1 Sites G, H, I and L; and potential adverse impacts from the southern portion of the W. G. Krummrich Facility and other industries in the Sauget area.

Solutia submitted the Pre-Final Design for the Sauget Area 2 Groundwater Migration Control System to USEPA on January 21, 2003. The GMCS Pre-Final Design consisted of a 3,300 ft. long, "U"-shaped, fully-penetrating barrier wall located downgradient of Sauget Area 2 Site R and three groundwater extraction wells on the upgradient side of the barrier wall (Figure 2-26). To facilitate completion of the GMCS, Solutia proceeded with construction of the groundwater extraction system at its own risk prior to USEPA design approval. Preparations for a treatability pilot test began in November 2002, and remedial action construction began in August 2003.

The middle of three extraction wells was installed in November 2002 to provide water for the treatability pilot test. Access for installation of a temporary 6-inch discharge pipeline was obtained and installation of this pipeline was completed in May 2003. Development of the center extraction well was also completed in May 2003 and the pilot treatability test was performed that month.

Installation of the two remaining extraction wells was started on May 20, 2003 and development of these wells was completed June 16, 2003. While well installation and development was underway, construction of the permanent 20-inch discharge pipeline was started on May 27, 2003. On June 3, 2003, construction of the electrical supply system and the instrumentation and control system were started.

Solutia submitted the Final Design for the Sauget Area 2 Groundwater Migration Control System to USEPA on July 3, 2003. Mobilization for barrier wall construction began on August 18, 2003 and pre-trenching along the barrier wall alignment was initiated on August 29, 2003. Slurry trench excavation started on September 4, 2003. USEPA approved the Sauget Area 2 Groundwater Migration Control System Final Design on October 16, 2003. Backfilling of the slurry trench was completed on November 8, 2004. Total construction and operation costs in 2003/2004 were an estimated \$25.4M.

Pumping from the Sauget Area 2 Groundwater Migration Control System and discharge to the American Bottoms Regional Treatment Facility started on July 12, 2003 at the flow rate mandated by the POTW. On September 15, 2003, which was 65 days after start of pumping, American Bottoms Regional Treatment Facility agreed to increase the discharge rate to 1,000 gpm over an eight to nine day period with an additional increase to a total of 1,350 gpm 30 days thereafter if its system acclimated to the 1,000 gpm flow. American Bottoms Regional Treatment Facility also indicated that "the American Bottoms Plant should be able to accept up to 2,000 gpm". Discharge at 1,000 gpm was started on September 29, 2003 (79 days after start of pumping) and increased to 1,250 gpm on October 7, 2003 (87 days after start of pumping). Full discharge, to the "maximum necessary", was authorized by American Bottoms Regional Treatment Facility 14 days later on October 21, 2003 and was started on October 22, 2003. Total pumping capacity of the three GMCS extraction wells is 2,200 gpm.

The design basis for the GMCS was consistent with the Record of Decision (ROD) requirement to:

"address the release of contaminated groundwater in the vicinity of Site R and the associated risks ... [by installing] three partially penetrating groundwater recovery wells capable of pumping a total of 303 to 724 gpm ... [that] will be installed inside the "U"-shaped barrier wall to abate groundwater moving into the wall".

To meet this ROD requirement, the Sauget Area 2 Groundwater Migration Control System is operated so that the amount of groundwater extracted from the "U"-shaped barrier wall is to equal the amount of groundwater that flows into it (i.e.  $Q_{In} = Q_{Out}$ ). Darcy's Law, which is given below, governs the amount of groundwater discharging into the upgradient open end of the GMCS barrier wall:

$$Q = KIA$$

Where:

Q	=	Groundwater Discharge into Barrier Wall
K	=	Aquifer Hydraulic Conductivity (1E-1 cm/sec or 285 ft/day)
I	=	Groundwater Gradient (Average of PZ-5 U/D and PZ-8 U/D)
A	=	Groundwater Discharge Area (209,522 square feet)

Hydraulic conductivity was established using regional information on hydraulic characteristics of the American Bottoms aquifer. Groundwater gradient is determined using dynamic, real-time groundwater level measurements from piezometer pairs PZ-5 U/D and PZ-8 U/D. Groundwater discharge area is determined by multiplying the actual seepage face length of 2,095.22 feet, which is the distance between the north and south wings at the open end of the "U"-shaped barrier wall, by the measured aquifer saturated thickness.

### 3.0 REMEDIAL INVESTIGATION (1999 to 2000)

#### 3.1 Remedial Investigation Objectives and Approach

The January 21, 1999 AOC Scope of Work identified the additional Site characterization data required to define and evaluate removal/remedial action alternatives for Sauget Area 1. A Field Sampling Plan (FSP) was prepared by O'Brien & Gere Engineers, Inc. (OBG), on behalf of Solutia Inc., to implement the SSP. The FSP was designed to achieve the objectives of the SSP and the AOC as described in Section 1.0 of this report. OBG was also responsible for the implementation of the FSP, which commenced in September 1999 and was completed in April 2000. After completing field work in 2Q00, OBG prepared a Data Report (O'Brien & Gere, 2001) and a Field Sampling Report (O'Brien & Gere, 2000b). An outline of the work undertaken in 1999-2000 is presented below:

Area of Investigation	Investigation Objective	Investigation Approach
<b>Source Areas</b>	Boundary Confirmation	<ul style="list-style-type: none"> <li>• Boundary Delineation Trenches</li> <li>• Soil Gas Surveys</li> </ul>
	Buried Drum and Tank Identification	<ul style="list-style-type: none"> <li>• Magnetometer Survey</li> <li>• Anomaly Trenches</li> </ul>
	Soil and Waste Characterization	<ul style="list-style-type: none"> <li>• Surface Soil Sampling</li> <li>• Subsurface Soil and Waste Sampling</li> </ul>
	Soil, Waste and Leachate Treatability	<ul style="list-style-type: none"> <li>• Thermal Desorption Treatability Study</li> <li>• Incineration Treatability Study</li> <li>• Leachate Treatability Study</li> </ul>
	Vapor/Dust Entrainment	<ul style="list-style-type: none"> <li>• Upwind Ambient Air Sampling</li> <li>• Downwind Ambient Air Sampling</li> </ul>
	Groundwater Characterization	<ul style="list-style-type: none"> <li>• Upgradient Groundwater Sampling</li> <li>• SHU Groundwater Sampling</li> <li>• MHU/DHU Groundwater Sampling</li> <li>• Alluvial Aquifer/Bedrock Interface Groundwater Sampling</li> </ul>
<b>Groundwater</b>	Aquifer Properties Determination	<ul style="list-style-type: none"> <li>• Grain Size Analysis</li> <li>• Hydraulic Conductivity (Slug) Tests</li> </ul>
	Groundwater Flow Direction Determination	<ul style="list-style-type: none"> <li>• Groundwater Level Piezometer Installation and Measurement</li> </ul>
	Groundwater Migration Evaluation	<ul style="list-style-type: none"> <li>• Downgradient Groundwater Sampling</li> </ul>
	Residential Area Groundwater Quality Evaluation	<ul style="list-style-type: none"> <li>• SHU Time-Series Sampling</li> <li>• Domestic Well Sampling</li> </ul>
<b>Floodplain Soils</b>	Overbank Flooding and Wind-Blown Dust Evaluation	<ul style="list-style-type: none"> <li>• Background Soil Sampling</li> <li>• Surface and Subsurface Floodplain Soil Sampling</li> </ul>

Seven hundred forty-eight media samples and 328 QA/QC samples were collected during the 1999 to 2000 Remedial Investigation resulting in 6,635 chemical and physical property analyses (Table 3-1). Quality assurance and quality control (QA/QC) samples collected during the sampling programs generally consisted of the following:

- One duplicate per 10, or fraction of 10, environmental samples collected;
- One matrix spike/matrix spike duplicate (MS/MSD) per 20, or fraction of 20, environmental samples collected or one MS/MSD every three working days, whichever was sooner;
- One environmental blank (or field blank) per 10, or fraction of 10, environmental samples collected unless dedicated or disposable sampling equipment was used to collect samples; and
- One trip blank per sample cooler containing environmental samples for VOC analysis.

Data collected pursuant to the FSP and field changes to the FSP were found to be inadequate for proper site characterization in some instances. In particular, Toxicity Characteristic Leaching Potential (TCLP) tests performed on composite waste samples were not adequate to characterize the nature and extent of contamination in the disposal areas. The TCLP analyte list does not include many of the contaminants that can be expected at the Site. Compositing the samples resulted in the inability to identify the vertical extent of potential hot spots within the fill areas. TCLP results cannot be evaluated against appropriate standards for protection of human health or groundwater quality, resulting in the inability to assess the magnitude of potential source impacts. In addition, no testing was performed on samples of solid or liquid wastes that were exposed during test trenching and waste boring tasks. In those instances where the data collected during the 1999/2000 Remedial Investigation were inadequate, data from previous investigations summarized in the 1998 Ecology & Environment report were used to more fully characterize site conditions.

Data collection activities and results are described in the following sections:

- **Section 3.2 Source Area Investigation**

- 3.2.1 Source Area Boundary Investigation
- 3.2.2 Source Area Buried Drum and Tank Investigation
- 3.2.3 Source Area Soil and Waste Investigation
- 3.2.4 Source Area Soil, Waste and Leachate Treatability Studies
- 3.2.5 Source Area Ambient Air Investigation
- 3.2.6 Source Area Groundwater Investigation

- **Section 3.3 Downgradient Groundwater Investigation**

- 3.3.1 Downgradient Groundwater Investigation Sampling
- 3.3.2 Downgradient Groundwater Investigation Results

- **Section 3.4 Surface Water and Sediment Investigation**

- 3.4.1 Surface Water Investigation
- 3.4.2 Sediment Investigation

- **Section 3.5 Soil Investigation**

- 3.5.1 Background Soil Investigation
- 3.5.2 Floodplain Soil Investigation

## **3.2 Source Area Investigation**

### **3.2.1 Source Area Boundary Investigation**

#### **3.2.1.1 Boundary Delineation Trenches**

Prior to performing any environmental sampling at the source areas, several tasks were performed to ensure that the boundaries of these areas were adequately delineated. This work included viewing historical aerial photographs, performing elevation surveys at the sites, reviewing topographic maps, and installing boundary test trenches. Details and supporting information concerning these tasks are included in Volume 1 of the Field Sampling Report (Non-measurement Data Acquisition).

Boundary confirmation trench locations at Sites G, H, I, L and N are shown on Figures 3-1, 3-2, 3-3, 3-4 and 3-5, respectively. Installation of these test trenches confirmed the source area boundaries identified through historical aerial photograph analysis. The original plan was to excavate a trench on each side of each fill area (four trenches per site). However, due to access limitations, the number of trenches varied per site. Additionally, eight test borings were substituted for test trenches on the west border of Site G (i.e., at the Wiese property) where access was an issue. In all, a total of 22 trenches were excavated at Sites G, H, I, L, and N and eight test borings were installed at Site G at the Wiese property to confirm disposal area boundaries.

For additional information pertaining to the trenching operation and copies of field logs, records, and color digital photographs for the boundary trenches at Sites G, H, I, L, and N, refer to the Field Sampling Report (Volume 1, Section 3.1). For copies of field records pertaining to the eight test borings at the Wiese property at Site G, refer to the Field Sampling Report (Volume 8, Appendix D, Record Book #3, pp. 155-167).

#### **3.2.1.2 Soil Gas Surveys**

Soil gas survey were conducted at Sites G, H, I, L, and N using a shallow soil probe to collect samples from a depth of five feet sample below ground surface. Collected vapors were analyzed on site for Total VOCs. Soil gas samples were collected at an approximate frequency of one sample per acre. Each disposal area was divided into a 200 ft. by 200 ft. grid and soil gas samples were collected at the approximate center point of the grid cell using the following grids:

Site	Sampling Grid Size (Feet)	Grid Cell Size (Feet)	No. of Soil Gas Samples
G	400 x 600	200 x 200	6
H	400 x 800	200 x 200	8
I	400 x 1200	200 x 200	12
L	200 x 200	200 x 200	1
N	300 x 300	200 x 200	2
Total Number of Soil Gas Samples			29

When detectable concentrations of VOCs were found in a sample, the soil gas survey was extended beyond the grid cell boundaries. A total of 36 additional soil gas samples were collected perpendicular to the Fill Area grid cells (see table below). Soil gas samples were collected at 100 ft. intervals (0, 100 and 200 ft. away from the edge of the grid cell) along four 200 ft.-long transects; one sampling transect located perpendicular to each side of the grid cell.

Site	No. of Soil Gas Sampling Transects	No. of Soil Gas Samples
G	2	6
H	4	10
I	3	10
L	4	10
N	0	0
Total Number of Samples		36

Soil gas sample locations at Sites G, H, I, L and N are shown on Figures 3-1, 3-2, 3-3, 3-4 and 3-5, respectively. Field logs, notes, and graphs developed during the soil gas survey program are provided in the Field Sampling Report (Volume 1).

### 3.2.1.3 Source Area Boundary Investigation Results

All four boundaries of Sites G, H, L, and N identified by air photo analysis were confirmed by soil gas surveys (VOCs detected inside the boundaries but not outside) and by boundary trenching or Site G West boundary delineation borings (waste observed inside the boundaries but not outside). The notes from the boundary test trenching can be found in Volumes 8 and 9 of the Field Sampling Report (O'Brien & Gere, 2000) and in Attachment D of the "Evaluation of Buried Drums" (GSI, 2006).

The eastern portion of Site G is within a fenced area and is covered with vegetation. In previous Sauget Area 1 reports, the disposal area boundary shown on site maps coincides with the fenced area. However, source area boundary investigation results (Figure 3-1) and review of historical aerial photographs (Figures 2-28, 2-29, and 2-30) indicate that waste and fill materials are not present within the southern portion of the fenced area but are present west of the fenced portion of Site G beneath the Wiese parking lot and building. The portion of Site G that extends onto the Wiese property is labeled Site G West.

Site I was considered to be a single site when the source area boundary investigation was performed in 1999-2000. However, Site I has since been divided into two areas, Site I South and Site I North, based on review of historical aerial photographs and observations during interior test trenching, as described in Section 3.2.2.3. The boundary between Site I South and Site I North is visible on historical aerial photographs dated 1950, 1955, and 1962 (see Figures 2-28, 2-29, and 2-30). Site I North contains inert fill material, rather than waste.

The boundaries of Site I South are defined by general knowledge of the fill extent to the south (bounded by Queeny Road), to the west (bounded by the former location of Dead Creek), and to the north (bounded by Site I North, as shown on the historical aerial photos). The eastern boundary of Site I South was identified based on a trench excavated during the source area boundary investigation (see Boundary Trench 2 on Figure 3-3),

The boundaries of Site I North are defined by general knowledge of the fill extent to the south (bounded by Site I South as shown on the historical aerial photos), to the west (bounded by the former location of Dead Creek), and to the east (bounded by Falling Springs Road). The northern boundary of Site I North was investigated during the source area boundary investigation (see Boundary Trench 1 on Figure 3-3),

### **3.2.2 Source Area Buried Drum and Tank Investigation**

#### **3.2.2.1 Magnetometer Survey**

Magnetometer surveys were conducted at Sites G, H, I, L, and N to identify anomalies indicative of drum disposal or buried tanks. The following tasks were performed for each survey:

- Magnetometer measurements were made at locations determined by superimposing an approximate 50 ft. by 50 ft. grid on the disposal areas. The magnetometer survey was conducted with a Geometrics 856 Total Field Magnetometer. Operation of equipment and calibration of instruments were in accordance with the manufacturer's recommended field procedure and application manual.
- Magnetometer measurement points were located in the field using known points such as buildings, roads, or other fixed features or by using Global Positioning System (GPS).

The total number of measurements completed for each Site is presented below:

Site	Magnetometer Measurements
G	77
H	106
I	255
L	19
N	86
Total Number of Magnetometer Measurements	543

After the magnetometer surveys were completed, maps were developed that showed the distribution of

magnetic field strength over the five sites. These maps were compared with the observed field conditions (including the location of known interfering objects such as vehicles, overhead power lines, and surface debris). Magnetic anomalies that could not be explained by observed site conditions were presumed to be the result of buried metallic subsurface material (drums, tanks, debris, etc.). These data were used to strategically place the anomaly confirmation trenches discussed in the next section. Additional information pertaining to the magnetometer survey, equipment used, and procedures are in the Field Sampling Report (Volume 1, Section 3.4).

### **3.2.2.2 Anomaly Trenches**

To evaluate whether the anomalies detected during the magnetometer surveys were associated with buried drums or tanks, test trenches were dug in the interior of each disposal area at anomalies that coincided with the following findings:

- Elevated groundwater concentrations as identified by the 1998 Ecology and Environment Data Report;
- Total VOC detections from the soil gas survey;
- Magnetic anomalies identified during the 1988 Ecology and Environment geophysical survey; and
- Areas of drum or tank disposal identified during historical aerial photograph analysis of disposal area boundaries.

One anomaly trench each was excavated in the interior of Sites G, H, L, and N and two trenches were excavated in the interior of Site I. One of the Site I anomaly trenches falls within Site I South and the other is at Site I North. Anomaly trenching was conducted as described below:

- Anomaly trenches were advanced until evidence as to the source of the anomaly was located.
- Spoils from the trenching operation were placed on polyethylene sheeting, and the stockpile was sloped to allow any excavated liquids to drain back to the trench.
- At the completion of the excavation, the spoils were returned to the excavation and the site was restored.

Anomaly trench locations for Sites G, H, I L and N are shown on Figures 3-1, 3-2, 3-3, 3-4 and 3-5, respectively. For additional information pertaining to the trenching operation and copies of field logs, records, and color digital photographs, refer to the Field Sampling Report (Volume 1, Section 3.5). Each of the source areas was restored to its original condition at the conclusion of trenching operations.

### **3.2.2.3 Source Area Buried Drum and Tank Investigation Results**

Interior test trenches were excavated at each of the source areas to confirm the presence or absence of buried metallic containers (tanks or drums). One interior trench was excavated at Sites G, H, L, and N and two trenches were excavated at Site I, one located at Site I South and one at Site I North, to determine whether or not magnetic highs detected during the magnetometer survey were caused by buried tanks and/or drums. The notes from the interior test trenching can be found in Volumes 8 and 9 of



the Field Sampling Report (O'Brien & Gere, 2000) and in Attachment D of the "Evaluation of Buried Drums" (GSI, 2006).

Most of the waste encountered during the interior test trenching consisted of glass containers, wood and metal debris, paper documentation (bill of lading, invoices, brochures, etc.) and miscellaneous trash. Uncontained solid and liquid wastes were also uncovered during trenching. Although the investigation targeted potential hot spots, no intact buried tanks or drum caches were located. However, test trenching exposed partially or fully-crushed drums and drum fragments in each of the disposal areas with several of the drums still containing waste products.

None of the drums that were located during the drum and tank identification study were intact except for one intact drum that was located during a fill area boundary confirmation trench at Site G, over-packed and removed. The drums in the interior anomaly trenches were either crushed or rusted and were not capable of holding liquid contents. Solid contents were noted in some of the buried drums.

At Site G, a damaged drum that was exhumed smoked upon exposure to the atmosphere, a sign of pyrophoric material. This smoking drum was removed and then placed back into the trench at 17 feet bgs, the depth to groundwater. Several other damaged drums at Site G had solid media, described as a shiny black tar-like substance, in them. Another drum had a bright orange solid material. A yellowish, green substance was identified covering rocks at the groundwater interface at the bottom of the anomaly trench and a green oily substance was reported to be floating on the groundwater table.

The only evidence of drums in the trenches at Site H was partial drums and drum fragments. Throughout substantive portions of the interior test trench at Site H, contaminated waste soil was identified and described as very dark, uniform, black, fine, and silty.

The first four damaged drums found in the anomaly trench at Site I South were co-located. Some solid yellowish material was reported in the drum(s). The third damaged drum had a white solid near it. The anomaly trench at Site I North encountered bricks, pieces of concrete, large concrete slabs, rebar, sheet metal, other metal scrap, and wood. No evidence of drums was observed in the anomaly trench at Site I North.

Damaged drums in the Site L anomaly trench were described as containing a black and powdery material, a black semi-solid material, a black tar-like material that leaked from some drums, a tannish-brown material that leaked from a drum, and a whitish material in and around drums. A note in the FSR stated that "additional drums were likely in the southern area of the trench" though the test trenching was terminated.

At Site N several damaged drums in the anomaly trench were described as containing a pasty, whitish material. The PID readings for the white material were between 800 and 900 ppm, which were the highest readings for all exhumed waste media from Site N. The pasty whitish material could have been painting waste, which would be consistent with the former use of Site N for disposal of construction debris. Site N is located on property formerly owned by the H. Hall Construction Company.

Section 5.2.3.1 of this report provides a detailed inventory of the buried drums found at Sauget Area 1

during boundary and interior trenching in 1999-2000 and during supplemental investigations performed by Tetra Tech in 2002-2003.

### **3.2.3 Source Area Soil and Waste Investigation**

#### **3.2.3.1 Surface Soil Sampling**

A discrete surface soil sample, from 0 to 0.5 feet, was collected at the location of each of the four subsurface soil and waste characterization borings installed at Sites G, H, I, L and N prior to installation of the borings (Figures 3-1, 3-2, 3-3, 3-4 and 3-5, respectively). Samples were analyzed for VOCs, SVOCs, pesticides, herbicides, PCBs, dioxins and metals. Nomenclature used for these analyses was as follows: WASTE-G-B1-0-0.5FT. The "WASTE" nomenclature identifies the sample as a fill area sample; "G" identifies the fill area that the sample was collected from; "B1" identifies the boring number (four sample borings per fill area); and "0-0.5 FT" identifies the sample interval (0-0.5 feet for all discrete surface samples).

Analytical data summary statistics (frequency of detection and minimum, average and maximum constituent concentrations) for surface soils at Sites G, H, I South, I North, L and N are presented in Tables 3-2, 3-3, 3-4A, 3-4B, 3-5 and 3-6, respectively.

#### **3.2.3.2 Subsurface Soil and Waste Sampling**

The following tasks were performed to characterize subsurface soils and wastes within Sites G, H, I, L and N:

- Five soil borings were advanced at each of Sites G, H, I, L, and N using conventional hollow-stem auger drilling methods.
- Continuous soil samples were collected from the ground surface to approximately two feet below the bottom of the fill material in four of the five borings per site. These borings are referred to as "sample borings" in this document and in the Field Sampling Report.
- In one of five soil borings per site, native soil below the fill material was field screened for VOCs using a photoionization detector (PID). This screening was conducted to a depth of 10 to 15 feet below the fill material. These borings are referred to as "screen borings" in this document and in the Field Sampling Report.
- One composite waste sample was collected at each "sample boring" location and analyzed for waste characteristics (ignitability, corrosivity, reactivity and TCLP). Visual observations (discoloration, presence of foreign objects, etc.) and PID readings were used to identify whether waste was present in a continuous boring sample.

Boring locations are shown on Figures 3-1, 3-2, 3-3, 3-4 and 3-5 for Sites G, H, I, L and N, respectively. A copy of the boring logs, field notes, color digital photographs, and more detailed descriptions of work performed in the field are presented in the Field Sampling Report (Volume 1, Section 3.3).

Samples were analyzed for waste characteristics - ignitability, corrosivity, reactivity and TCLP. Nomenclature used for the waste composite samples was as follows: WASTE-G-B1-COMP. This nomenclature is the same as for the discrete surface samples except the letters "COMP" are inserted

instead of a sampling depth. The label "COMP" identifies that the sample was composited over the boring profile. Samples analyzed for VOCs were not composited due the potential loss of volatile organics. In these cases, the sample interval replaced COMP on the sample number. For samples that were not composited, the sample interval with the highest PID reading was submitted for analysis. Summary statistics for subsurface soil and waste characterization analyses of samples collected from Sites G, H, I, L and N are presented in Tables 3-7 to 3-11.

### 3.2.3.3 Source Area Soil and Waste Investigation Results

**Source Area Waste Volume** - Investigations completed during the SSP included the review of historical aerial photographs, performance of soil-gas and magnetometer surveys, and installation of test trenches and borings to delineate the disposal area boundaries. Estimated volume for each disposal area was based upon the surface area and a conservative estimate of the average waste depth determined during the SSP. Average depths were determined by reviewing the disposal area boring logs. Borings that encountered little or no waste were not used in determining average waste depths. Surface areas were determined by scaling the footprint depicted on the drawings. Volumes were then estimated by multiplying the scaled area by the average waste depth, and converting to cubic yards, as shown in the following table.

Estimated Sauget Area 1 Disposal Area Waste Volumes			
Disposal Area	Disposal Area Areal Extent (Acres)	Average Estimated Waste Thickness (Feet)	Estimated Waste Volume (Cubic Yards)
Site G + Site G West	3.32	20	107,000
Site H	4.87	20	157,000
Site I South	8.79	25	355,000
Site I North	5.87	6	56,800
Site L	1.08	10	17,500
Site N	3.84	16	103,000
			796,000

Collectively, Sites G, H, I South, I North, L and N contain an estimated 796,000 cubic yards of soil and waste. Site I South is the largest disposal area with an estimated waste volume of 355,000 cubic yards followed by Site H with 157,000 cubic yards and Site G plus G West with 107,000 cubic yards. All three of these sites were formerly used for industrial/municipal waste disposal. Estimated waste volume in Site L is much smaller, 17,500 cubic yards. Site L is a backfilled wastewater impoundment, Site N contains an estimated volume of 103,000 cubic yards, and Site I North contains an estimated volume of 56,800 cubic yards. Site N is an inactive construction debris disposal area on the former H.H. Hall Construction Company property, and Site I North is a former fill area that contains broken concrete, bricks, scrap metal, wood, and soil.

**Source Area Waste Characterization** - Disposal area waste characterization investigations completed during the SSP included installation of interior test trenches, performance of soil and waste borings and collection of subsoil and waste characterization samples. Waste materials encountered at Sites G, H, I South, L and N included crushed or partially-crushed drums, drum fragments and remnants, uncontained solid and liquid wastes, wood, glass, paper, construction debris and miscellaneous trash. The fill material

encountered at Site I North included bricks, pieces of concrete, large concrete slabs, rebar, sheet metal, other metal scrap, and wood. No evidence of drums was observed in the anomaly trench at Site I North. Although the SSP investigation targeted potential hot spots in each disposal area, no significant residual wastes were identified during these investigations. Crushed or partially crushed drums and drum remnants were discovered at each site. However, only one intact drum was found (Site G). No surface leachate breakouts or discharges were observed at any of the disposal areas.

Corrosivity, ignitability and reactivity for the waste samples collected at Sites G, H, I, L and N are summarized below:

**Summary of Maximum Detected Corrosivity, Ignitability and Reactivity Data from Site G, H, I, L and N Waste Samples**

Waste Characteristic	Site G	Site H	Site I	Site L	Site N
Corrosivity, pH (S.U.)	3.16 to 9.28	6.02 to 9.64	7.19 to 11.05	7.48 to 9.85	7.28 to 9.80
Ignitability, Flash Point (Degrees)	NIVO	NIVO	NIVO	NIVO	NIVO
Total Releasable Cyanide, mg HCN	ND (100)	ND (100)	ND (100)	ND (100)	ND (100)
Total Cyanide, mg/l	3.6	ND (0.67)	1.1	ND (0.64)	ND (0.58)
Total Releasable Sulfide, mg H <sub>2</sub> S	ND (50)	730	ND (50)	480	ND (50)

Notes: 1) NIVO = No apparent ignition of vapor over sample was observed  
2) ND = Not detected at the detection limit within parentheses  
3) Source: O'Brien & Gere, 2001

**Site G Waste Characterization** - Test trenching at Site G revealed the presence of crushed or partially-crushed drums and drum fragments, some containing waste materials. Material within one drum generated smoke when it was uncovered, indicating the presence of pyrophoric materials. Other uncontained solid wastes were encountered during trenching. A yellowish-green material was observed covering some rocks at the water table. One intact drum was found, which was over-packed and disposed of off-Site. Site G subsoil and waste borings encountered oily wastes and an unidentified yellow substance. Maximum PID readings ranged up to 1367 ppm for materials recovered in the waste borings. TCLP analyses indicate that materials encountered in Site G can be classified as hazardous waste exhibiting the characteristic of toxicity.

Summary statistics for historical Site G subsurface soil and waste analytical data are included in Table 3-12 and summary statistics for constituents detected more than once in the historical data are summarized below:

**Maximum, Minimum and Mean Concentrations of Constituents Detected More Than Once In Site G Wastes**

Detected Constituents		Number of Detects	Minimum Detected Concentration (mg/kg)	Mean Detected Concentration (mg/kg)	Maximum Detected Concentration (mg/kg)
VOCs	Acetone	11	0.032	5.66	15.4
	Benzene	6	0.003	15.3	45.3
	2-Butanone (MIBK)	11	0.022	7.9	17.8
	Chlorobenzene	8	0.107	108	538
	Dichloromethane	11	0.003	1.63	7.11
	Ethylbenzene	6	0.164	6.80	16.9
	4-Methy-2-Pentanone (MIBK)	4	0.635	2.99	6.00

	Tetrachloroethene	8	0.009	18.8	58.6
	Toluene	6	0.406	48.5	118
	Trichloroethylene	4	0.762	1.94	3.85
	Xylenes, Total	6	0.092	16.4	41.5
SVOCs	4-Chloroaniline	3	5.97	81.6	231
	Dibenzofuran	2	4.30	19.1	33.8
	1,4-Dichlorobenzene	2	2.38	2.97	3.56
	2,4-Dichlorophenol	3	14.1	64.5	141
	Di-n-butylphthalate	4	0.279	8.92	17.6
	Hexachlorobenzene	2	27.9	34.3	40.6
	2-Methylnapthalene	4	8.71	18.4	37.1
	Napthalene	7	4.83	893	5,430
	Phenanthrene	4	12.9	28.4	51.4
	Pyrene	2	7.56	13.3	19.1
	1,2,4-Trichlorobenzene	4	7.87	61.6	120
Pesticides	4,4'-DDE	4	3.07	48.8	135
Herbicides	Pentachlorophenol	5	23.5	1,320	4,770
PCBs	Total PCBs	7	13.0	90.8	4,430
Metals	Copper	20	8.0	173	2,220
	Lead	18	3.0	241	3,120
	Nickel	19	8.0	51.3	399
	Zinc 19	27.0	475	4,260	

- Notes: 1) Target metals reported in this table; all detected metals reported in Table 3-12  
2) Historical data from Ecology and Environment, 1988 and 1998

The greatest concentrations in subsurface soils at Site G were detected at depths between 10 to 25 feet below ground surface (bgs).

**Site H Waste Characterization** - As discussed above, anomaly trenching in Site H revealed the presence of crushed or partially-crushed drums and drum fragments, at least one of which contained waste solid material. Other materials encountered included brick, wood, plastic and other refuse. A variety of materials were encountered in Site H borings, but no specific uncontained waste substances were described in the field notes and logs. Waste materials found in six of the eight borings consisted of multicolored sludges, solids, and oily refuse underlying the fill. Maximum PID readings ranged up to 2000 ppm. Results from TCLP analyses indicate that materials encountered in Site H can be classified as hazardous waste exhibiting the characteristic of toxicity.

Summary statistics for historical Site H subsurface soil and waste analytical data are included in Table 3-13 and summary statistics for constituents detected more than once in the historical data are summarized below:

**Maximum, Minimum and Mean Concentrations of Constituents Detected More Than Once In Site H Wastes**

Detected Constituents		Number of Detects	Minimum Detected Concentration (mg/kg)	Mean Detected Concentration (mg/kg)	Maximum Detected Concentration (mg/kg)
VOCs	Acetone	11	0.015	4.85	21.1
	Benzene	7	0.004	15.2	61.3
	2-Butanone (MIBK)	5	0.033	12.6	27.2
	Chlorobenzene	6	0.024	97.6	452
	Chloroform	2	0.053	0.123	0.192
	Dichloromethane	11	0.006	6.34	55.6

	Ethylbenzene	3	4.38	9.06	12.8
	4-Methy-2-Pentanone (MIBK)	4	0.009	2.33	7.85
	Toluene	5	0.145	22.8	76.5
	Xylenes, Total	3	1.51	14.8	23.6
SVOCs	Acenaphthylene	3	0.130	126	378
	Anthracene	4	0.129	170	680
	Benzo(a)anthracene	3	0.554	126	378
	Benzo(a)pyrene	2	0.780	136	272
	Benzo(b)fluoranthene	3	0.442	71.0	211
	Benzo(g,h,i)perylene	2	0.449	56.9	113
	Benzoic Acid	2	1.41	2.02	2.64
	Bis(2-ethylhexyl)phthalate	4	0.251	0.428	0.614
	Chrysene	3	0.750	112	332
	Dibenzofuran	4	0.143	15.5	60.4
	1,2-Dichlorobenzene	3	0.548	6,480	19,400
	1,3-Dichlorobenzene	3	7.65	87.6	242
	1,4-Dichlorobenzene	5	0.062	6,320	30,600
	2,4-Dichlorophenol	5	0.167	150	742
	Di-n-butylphthalate	8	0.343	4.03	25.7
	Fluoranthene	4	0.145	333	1,330
	Fluorene	3	0.247	161	483
	2-Methylnapthalene	3	0.156	116	347
	Napthalene	4	0.044	567	2,270
	Phenanthrene	6	0.047	353	2,110
	Pyrene	3	0.935	222	664
	1,2,4-Trichlorobenzene	6	0.061	1,330	7,580
	2,4,6-Trichlorophenol	2	0.179	307	613
Pesticides	4,4'-DDE	2	0.504	0.642	0.780
	4,4'-DDT	2	0.780	0.852	0.923
PCBs	Total PCBs	7	0.251	2,730	18,000
Metals	Copper	8	3.0	536	2,440
	Lead	2	4.0	577	1,150
	Nickel	10	4.0	1,770	15,100
	Zinc	11	8.0	4,740	39,500

Notes: 1) Target metals reported in this table; all detected metals reported in Table 3-13  
2) Historical data from Ecology and Environment, 1988 and 1998

Based upon results of previous investigations (Ecology and Environment, 1988 and 1998), contaminant concentrations were generally higher in the central and northern portions of Site H compared to the southern portion. Highest concentrations were generally from samples collected from 10 to 25 feet bgs.

**Site I South Waste Characterization** - Crushed or partially crushed drums and drum fragments, some containing waste materials, were found in the Site I South anomaly trench. Material within some of the drums was described as a solid, yellowish material. Other uncontained solid wastes were encountered during trenching, including contents leaking out of broken drums. Black soil, bricks, wood, and metal scraps were also encountered in the anomaly trenches. Materials encountered in Site I South borings included uncontained solid wastes described as white and metallic shiny substances. Maximum PID readings ranged up to 2000 ppm for materials recovered in the waste borings. TCLP analyses indicate that materials encountered in Site I South can be classified as hazardous waste exhibiting the characteristic of toxicity.

Summary statistics for historical Site I South subsurface soil and waste analytical data are included in Table 3-14 and summary statistics for constituents detected more than once in the historical data are summarized below:

Maximum, Minimum and Mean Concentrations of Constituents Detected More Than Once In Site I South Wastes

Detected Constituents		Number of Detects	Minimum Detected Concentration (mg/kg)	Mean Detected Concentration (mg/kg)	Maximum Detected Concentration (mg/kg)
VOCs	Acetone	16	0.549	6.66	16.9
	Benzene	10	0.023	3.81	24.1
	2-Butanone (MIBK)	15	0.012	6.86	16.9
	Chlorobenzene	12	0.010	34.7	127
	Dichloromethane	16	0.007	1.52	6.77
	Ethylbenzene	10	0.096	4.65	15.1
	4-Methy-2-Pentanone (MIBK)	2	0.001	2.08	4.16
	Tetrachloroethene	5	0.612	2.57	5.27
	Toluene	11	0.048	11.3	77.9
	1,1,1-Trichloroethane	2	0.432	1.06	1.69
	Trichloroethylene	2	0.648	2.23	3.81
	Xylenes, Total	10	0.008	4.96	19.2
SVOCs	Anthracene	2	23.1	113	203
	Benzo(a)anthracene	2	2.47	4.59	6.72
	Benzo(b)fluoranthene	2	1.51	17.0	32.4
	Bis(2-ethylhexyl)phthalate	7	2.38	34.9	131
	Chrysene	2	3.97	4.78	5.59
	1,2-Dichlorobenzene	6	2.68	82.9	324
	1,3-Dichlorobenzene	2	18.9	44.5	70.1
	1,4-Dichlorobenzene	8	1.60	255	1,840
	Di-n-butylphthalate	8	0.134	37.1	203
	Fluoranthene	3	8.91	76.9	203
	Fluorene	3	3.08	14.9	35.4
	Hexachlorobenzene	7	32.3	258	1,270
	2-Methylnaphthalene	7	1.70	38.5	169
	Naphthalene	7	1.10	98.1	515
	N-Nitrosodiphenylamine	2	45.9	73.1	100
	Phenanthrene	5	1.32	34.3	102
	Phenol	2	15.2	21.1	27.0
	Pyrene	4	2.21	19.6	49.3
	1,2,4-Trichlorobenzene	8	6.71	1,400	8,260
Pesticides	4,4'-DDD	2	6.64	18.2	29.7
PCBs	Total PCBs	5	20.4	181	343
Metals	Copper	8	23.0	298	630
	Lead	15	3.0	2,060	23,300
	Nickel	12	0.9	335	2,410
	Zinc	16	13.0	624	6,330

Notes: 1) Target metals reported in this table; all detected metals reported in Table 3-14  
2) Historical data from Ecology and Environment, 1988 and 1998

Waste material was noted in several borings in Site I South at depths below the water table and consisted of oily sand, clay, wood and cinders mixed with refuse. Contamination was detected at depths extending to 38 feet bgs.

**Site I North Waste Characterization** – Bricks, pieces of concrete, large concrete slabs, rebar, sheet metal, other metal scrap, and wood were found in the Site I North anomaly trench. Maximum PID readings ranged up to 21 ppm for materials recovered in the boring B3 and 1.1 ppm for fill material in boring B4. Concrete pieces were observed in borings B3 and B4 at maximum depths of 2 ft and 5 ft bgs, respectively.

One soil boring was drilled at Site I North during the historical investigation (Ecology and Environment, 1988 and 1998). This boring was at location EE-13 and was drilled to a depth of 27.5 ft bgs. The boring log indicates that there was four feet of fill consisting of sandy clay and a mixture of crushed limestone, gravel, and concrete fragments. No soil samples from this historical boring were submitted for laboratory analysis (Ecology and Environment, 1988).

**Site L Waste Characterization** - Anomaly trenching in Site L revealed the presence of crushed or partially-crushed drums and drum fragments, some containing waste materials. A black tar-like substance was noted to be leaking from several drums. Other uncontained solid wastes were encountered during trenching. Other materials encountered in Site L trenching include bricks, rags, small pieces of concrete, and various other refuse. Discovery of crushed or partially crushed drums and the likelihood of more drums noted by the O'Brien and Gere in field notes, indicates that Site L was used for more than disposal of wash water from truck-cleaning operations. A variety of fill materials were encountered in Site L borings, but no specific uncontained waste substances were described in the field notes and logs. Maximum PID readings ranged up to 728 ppm for materials recovered in the waste borings. TCLP analyses did not indicate that materials encountered in Site L exhibited the characteristic of toxicity.

Summary statistics for historical Site L subsurface soil and waste analytical data are included in Table 3-15 and summary statistics for constituents detected more than once in the historical data are summarized below:

**Maximum, Minimum and Mean Concentrations of Constituents Detected More Than Once In Site L Wastes**

Detected Constituents		Number of Detects	Minimum Detected Concentration (mg/kg)	Mean Detected Concentration (mg/kg)	Maximum Detected Concentration (mg/kg)
VOCs	Acetone	6	0.015	1.01	4.56
	Benzene	5	0.004	2.01	5.70
	2-Butanone (MEK)	3	0.016	3.34	10.0
	Chlorobenzene	8	0.012	1.25	5.30
	Chloroform	3	0.049	6.80	20.3
	Dichloromethane	5	0.005	0.489	2.28
	4-Methy-2-Pentanone (MIBK)	4	0.008	0.073	0.167
	Toluene	7	0.050	66.5	400
	Xylenes, Total	4	0.179	3.10	11.0
SVOCs	Acenaphthene	3	0.044	1.08	3.10
	Anthracene	3	0.028	1.46	4.20
	Benzo(a)anthracene	4	0.075	2.46	8.60
	Benzo(a)pyrene	3	0.022	1.80	5.30
	Benzo(b)fluoranthene	3	0.058	1.88	5.40
	Benzoic Acid	2	0.049	1.62	3.20
	Bis(2-ethylhexyl)phthalate	6	0.017	0.921	2.20
	4-Chloroaniline	6	0.043	98.7	270
	2-Chlorophenol	3	0.013	1.59	2.60
	Chrysene	4	0.076	2.20	8.20
	Dibenzofuran	2	0.042	1.52	3.00
	1,2-Dichlorobenzene	4	0.010	3.50	7.70
	1,4-Dichlorobenzene	9	0.018	23.4	100
	2,4-Dichlorophenol	2	2.40	6.70	11.0
	Diethyl Phthalate	2	0.310	0.655	1.00
	Di-n-butylphthalate	4	0.171	1.28	2.78
	Fluoranthene	4	0.130	4.27	16.0
	Fluorene	2	0.79	2.54	5.00



	Indeno(1,2,3,c,d)pyrene	2	0.110	1.51	2.90
	2-Methylnapthalene	6	0.210	1.42	3.10
	3&4-Methylphenol	4	0.100	0.143	0.190
	4-Methylphenol	5	0.088	3.40	7.10
	Napthalene	4	0.096	2.02	7.30
	Phenanthrene	5	0.091	5.18	23.0
	Phenol	5	0.346	8.77	16.0
	Pyrene	4	0.130	5.96	23.0
	1,2,4-Trichlorobenzene	3	5.50	52.5	79.0
Herbicides	Pentachlorophenol	4	11.5	31.7	58.2
PCBs	Total PCBs	2	16.0	258	500
Metals	Copper	10	9.7	92.7	308
	Lead	13	0.220	74.6	664
	Nickel	10	21.0	378	2,390
	Zinc	11	6.4	534	4,240

Notes: 1) Target metals reported in this table; all detected metals reported in Table 3-15  
2) Historical data from Ecology and Environment, 1988 and 1998

Contaminants in Site L were generally detected at depths ranging from 5 to 15 feet bgs.

**Site N Waste Characterization** – Site N is located on property formerly owned by the H. Hall Construction Company and was primarily used for disposal of construction debris. The construction waste materials encountered in Site N trenches included bricks, concrete debris, rebar, metal pipes and cables, sheet metal, railroad ties, scrap lumber, telephone poles, crushed and partially crushed drums and drum lids, plastic sheeting, rags, scrap tires, various other refuse, and fill soil.

Some of the crushed or partially crushed drums and drum fragments contained waste materials. Whitish and pasty white substances were noted in several of the crushed and partially crushed drums. PID readings inside the excavated drums ranged up to 870 ppm. Other uncontained solid wastes were encountered during trenching, including a whitish material discharging from the northwest corner of the interior excavation that appeared similar to the material inside some of the crushed drums. The pasty whitish material noted in the damaged drums and in the interior trench could have been painting waste, which would be consistent with the former use of Site N for disposal of construction debris.

Materials encountered in Site N borings included an unidentified green material. Maximum PID readings ranged up to 65.7 ppm for materials recovered in the waste borings. TCLP analyses did not indicate that materials encountered in Site N exhibited the characteristic of toxicity. A limited amount of previous sampling and analytical data are available for Site N. Ecology and Environment (1998) indicated that VOC concentrations ranged up to 0.014 mg/kg in the two subsurface collected at Site N. SVOCs were detected at a maximum concentration of 2.28 mg/kg in the two subsurface samples. Pesticides and PCBs were not detected in either of the samples analyzed. Summary statistics for historical Site N subsurface soils and waste analytical data are presented in Table 3-16.

### 3.2.4 Source Area Soil, Waste and Leachate Treatability Studies

Pilot treatability tests were planned for waste area material, sediments, and leachate to evaluate specific remedial technologies identified in the AOC SOW (on-site thermal desorption and off-site incineration). In accordance with the approved Support Sampling Plan, no treatability tests were planned or executed for

contaminated groundwater. Sediments and waste area material were to be tested using both on-site thermal desorption and off-site incineration. However, the requirement to pilot test creek sediments was eliminated after the Time Critical Removal Action UAO (see Section 2.3.2) was modified on May 31, 2000 to include removal of sediments from Dead Creek. Furthermore, a thermal desorption contractor could not be located in the United States with the RCRA and TSCA permits required to thermally treat soil and waste materials containing dioxins and PCBs. Thus, the thermal treatment pilot-testing program was reduced to evaluating the feasibility of off-site incineration of disposal area materials.

Treatability evaluation and testing for waste materials and leachate are described below. For additional information pertaining to the procedures that were followed during field work or the pilot testing program, refer to Section 3.23 (Volume 6) of the FSR.

#### **3.2.4.1 Source Area Soil and Waste Treatability Evaluation**

One composite organic waste sample was produced by mixing materials generated from one waste boring at each of the fill areas (Boring B3 on Site G, B3 on Site H, B2 on Site I South, B4 on Site L, and B1 on Site N). Boring selection was based on PID readings and log descriptions recorded during boring advancement. The composite sample from these borings was submitted to SafetyKleen in Coffeyville, Kansas for waste profiling, characterization, and to determine the feasibility of treatment through incineration (pilot testing). SafetyKleen was the only incineration contractor that possessed the RCRA and TSCA permits required to process the Site waste materials.

After review of laboratory analysis of the composite sample, personnel at SafetyKleen determined that they would need to modify their incinerator to treat the emissions generated from the PCBs and from the volatile metals, especially arsenic and mercury. Other concerns identified with off-site incineration involved the heterogeneous nature of fill area waste and associated materials handling problems. Large pieces of concrete, brick and other debris were present in the waste materials and would cause problems in feeding the material into the incineration unit. Thus, a pre-treatment effort would be required to segregate debris that was not suitable for incineration. Given the potential exposure problems associated with material handling and the other problems stated above, it was determined by SafetyKleen and Solutia Inc. that incineration pilot testing of the disposal area materials was not feasible.

#### **3.2.4.2 Source Area Leachate Treatability Evaluation**

Leachate treatability pilot tests were conducted for Site G and Site I South to evaluate if pretreatment limits could be achieved prior to discharge to the American Bottoms Regional Treatment Facility. The purpose of the testing was to identify technically sound, operationally reliable and cost-effective technologies for treating leachate from Sauget Area 1 disposal areas in the event such leachate requires removal, treatment and subsequent discharge to the American Bottoms Regional Treatment Facility.

Leachate samples were collected from Site G and Site I South, one from each site, using the two-inch diameter leachate-sampling well installed at each of these fill areas. Each leachate sample consisted of 25 one-gallon plastic containers filled with leachate collected after purging approximately 80 gallons from the well. Leachate collected from both Site G and Site I South was shipped to the Advent Group, Inc.'s

(Advent's) treatability testing laboratory in Brentwood, Tennessee. Both samples were subsequently composited into a 55-gallon drum and sampled for characterization purposes. For additional information pertaining to the procedures that were followed during field work or the pilot testing program, refer to Section 3.23 (Volume 6) of the FSR. All leachate characterization data and treatability testing results are presented in Advent's November 2000 report (Advent, 2000).

Advent performed leachate treatability studies using the following technologies:

<u>Leachate Treatment Technology</u>	<u>Batch Test Method</u>
• Chemical precipitation using lime and caustic	Jar tests
• Oxidation with hydrogen peroxide and ozone	Jar tests
• Filtration	Filtration at various pore sizes
• Activated carbon adsorption	Isotherm and column tests
• Biological treatment	Batch tests

Treatability study results are summarized below:

- Metals can be effectively removed by pH adjustment and chemical precipitation.
- PCBs and total suspended solids can be effectively removed by filtration.
- Activated carbon adsorption can effectively remove VOCs, SVOCs, herbicides, PCBs and dioxins; however, total TOC loadings and adsorption rates indicate rapid column exhaustion rendering the technology more suitable as a final polishing step.
- Biological treatment (activated sludge) and oxidation (hydrogen peroxide or ozone) appear to be technically feasible options for treating the organics in the leachate

### **3.2.5 Source Area Ambient Air Investigation**

#### **3.2.5.1 Source Area Ambient Air Investigation Sampling**

Ambient air sample collection was performed to measure airborne levels of VOCs, SVOCs, PCBs, dioxin, and metals that may be emanating from the Site. An air sample collection and analytical test method was selected to measure airborne constituent levels over a 24-hour time period. A 24-hour sample duration was required to average the air emission differences that may occur from the daytime to nighttime cycle from on-site and off-site conditions and activities. Also, air sample collection locations were positioned at the Site to collect upwind and downwind samples for differentiation of constituents originating from the surrounding area and those originating from the Site. Air sampling locations for Site G, H, I and L are shown on Figure 3-6.

**VOCs-** Twenty-four-hour cumulative duration sorbent tube samples were collected over a one-day period using USEPA Method TO-1 sampling protocol (Appendix G of the 1999 FSP). Two upwind and two downwind sorbent tube samplers (two tubes each) were installed around Site G; and three upwind and six downwind sorbent tube samplers (two tubes each) were installed at Sites H, I, and L. Sampling

locations were selected in the field with the concurrence of USEPA Region V or its designee. Thirteen air samples were collected for analysis of the presence of volatile organics.

**SVOCs, PCBs and Dioxin** - Twenty-four hour cumulative-duration polyurethane foam (PUF) samples were collected over a one-day period using USEPA Method TO-13, TO-4, and TO-9 sampling protocols (Appendix G of the 1999 FSP). Two upwind and two downwind PUF samplers were installed around Site G; and three upwind and six downwind PUF samplers were installed at Sites H, I, and L. Sampling locations were selected in the field with the concurrence of the USEPA or its designee. Thirteen air samples were collected for the analysis of SVOCs (Method TO-13), PCBs (Method TO-4), and dioxin (Method TO-9).

**Metals** - Twenty-four hour cumulative-duration PM 2.5 samples were collected over a one-day period using USEPA Method 6010B sampling protocol (Appendix G of the 1999 FSP). Two upwind and two downwind PM 2.5 samplers were installed around Site G; and three upwind and six downwind PM 2.5 samplers were installed at Sites H, I, and L. Sampling locations were selected in the field with the concurrence of the USEPA or its designee. Thirteen air samples were collected for the analysis of metals. For more information concerning the air sampling procedures, or the supporting documentation, refer to Section 3.22 of the FSR (Volume 6).

### 3.2.5.2 Source Area Ambient Air Investigation Results

Upwind and downwind air sampling were performed to evaluate the potential release and migration of constituents from Sites G, H, I and L. Transport pathways of potential interest include direct volatilization and potential airborne transport of particulate matter containing constituents. Summary statistics for upwind and downwind samples collected at Sites G, H, I and L are presented in Tables 3-17 to 3-24. Site I South and Site I North were not evaluated separately during the sampling program and therefore cannot be discussed independently in the following data summary.

**VOCs** - Air sampling results indicate a net average increase (average downwind minus average upwind concentrations) in VOCs at all four fill areas; however, total VOCs were less than 1 mg/m<sup>3</sup> at all fill areas. The average net increase across all four fill areas was 0.334 mg/m<sup>3</sup>. Individual VOCs detected varied by fill area, but generally included petroleum-related VOCs and select chlorinated VOCs. Maximum detected upwind and downwind VOC concentrations at Sites G, H, I and L are summarized below:

Maximum Detected VOC Concentrations Upwind and Downwind of Sites G, H, I and L

Constituent	Site G		Site H		Site I		Site L	
	Upwind (ug/m <sup>3</sup> )	Downwind (ug/m <sup>3</sup> )	Upwind (ug/m <sup>3</sup> )	Downwind (ug/m <sup>3</sup> )	Upwind (ug/m <sup>3</sup> )	Downwind (ug/m <sup>3</sup> )	Upwind (ug/m <sup>3</sup> )	Downwind (ug/m <sup>3</sup> )
Acetone	ND	717	ND	24	229	ND	ND	ND
2-Butanone (MEK)	ND	16.8	ND	24.7	24	ND	ND	30.5
Ethylbenzene	2.79	13.3	ND	1.82	ND	1.69	1.31	ND
1,1-Dichloroethene	ND	ND	27.1	ND	ND	ND	ND	ND
Dichloromethane	146	2,420	ND	11	295	2,090	ND	890
4-Methyl-2-Pentanone (MIBK)	ND	61.9	ND	ND	ND	ND	ND	ND
Styrene	ND	15.9	ND	ND	ND	ND	ND	ND
Tetrachloroethene	ND	2.92	ND	0.909	ND	ND	ND	ND
Toluene	ND	159	ND	ND	ND	ND	ND	ND

1,1,1-Trichloroethane	ND	ND	ND	6.37	ND	ND	ND	ND
Trichloroethene	ND	ND	ND	3.44	4.8	ND	ND	ND

**SVOCs** - Average downwind SVOC concentrations were less than or equivalent to the average upwind concentration at Sites G and L. A net increase (downwind minus upwind) in average SVOC concentrations was observed at Site H (0.00025 mg/m<sup>3</sup>) and Site I (0.00063 mg/m<sup>3</sup>). Individual SVOCs detected at these fill areas included naphthalene and phthalate compounds. Maximum detected upwind and downwind SVOC concentrations at Sites G, H, I and L are summarized below:

Maximum Detected SVOC Concentrations Upwind and Downwind of Sites G, H, I and L

Constituent	Site G		Site H		Site I		Site L	
	Upwind (ug/m <sup>3</sup> )	Downwind (ug/m <sup>3</sup> )	Upwind (ug/m <sup>3</sup> )	Downwind (ug/m <sup>3</sup> )	Upwind (ug/m <sup>3</sup> )	Downwind (ug/m <sup>3</sup> )	Upwind (ug/m <sup>3</sup> )	Downwind (ug/m <sup>3</sup> )
Acenaphthene	0.0203	0.0237	0.021	0.0225	ND	0.0385	0.0336	0.0331
Bis(2-ethylhexyl)phthalate	0.07	0.0825	0.0525	ND	ND	0.0738	0.0738	0.0777
Dibenzofuran	0.0223	0.0254	0.0207	0.0213	ND	0.0385	0.0369	0.0372
1,2-Dichlorobenzene	ND	ND	ND	ND	ND	0.259	ND	ND
1,4-Dichlorobenzene	0.0162	ND	0.0494	0.0638	0.0846	0.42	ND	0.024
Diethylphthalate	0.0487	0.0254	0.0228	ND	ND	ND	0.0238	0.0324
Dimethylphthalate	0.0533	0.0464	0.0432	0.0729	0.0393	0.0585	0.0309	0.0405
Fluorene	0.0172	0.0237	0.0191	0.0201	ND	0.0325	ND	0.0297
2-Methylnaphthalene	0.12	0.114	0.0895	0.112	0.136	0.122	0.154	0.149
2-Nitroaniline	ND	ND	ND	ND	ND	0.0294	ND	ND
Phenanthrene	0.027	0.0323	0.0401	0.0304	0.0332	0.0594	ND	0.0367
Phenol	ND	ND	ND	ND	ND	ND	0.0604	ND

**PCBs and Dioxin** - No PCBs were detected at any sampling location. Dioxin TEQs were lower in downwind samples than upwind samples, with the exception of Site G where average dioxin TEQs in downwind samples (0.098 picograms/m<sup>3</sup>) were slightly higher than the upwind average (0.088 picograms/m<sup>3</sup>). The average dioxin TEQ concentration measured across all sampling stations at all four fill areas was 0.11 picograms/m<sup>3</sup>. These data indicate dioxin TEQs at the four locations are at or below expected background concentrations.

**Metals** - Maximum detected upwind and downwind target metals (copper, lead, nickel and zinc) concentrations at Sites G, H, I, and L are summarized below:

Maximum Detected Target Metal Concentrations Upwind and Downwind of Sites G, H, I and L

Constituent	Site G		Site H		Site I		Site L	
	Upwind (ug/m <sup>3</sup> )	Downwind (ug/m <sup>3</sup> )	Upwind (ug/m <sup>3</sup> )	Downwind (ug/m <sup>3</sup> )	Upwind (ug/m <sup>3</sup> )	Downwind (ug/m <sup>3</sup> )	Upwind (ug/m <sup>3</sup> )	Downwind (ug/m <sup>3</sup> )
Copper	0.108	0.102	0.75	0.583	0.313	0.208	ND	ND
Lead	0.285	0.307	0.0229	0.0267	0.0221	0.0263	0.3	0.281
Nickel	ND	ND	ND	ND	ND	ND	0.00583	ND
Zinc	ND	ND	ND	ND	ND	ND	ND	ND

Total metals were lower in downwind samples than upwind samples, with the exception of Site H where average total metals in downwind samples (0.0013 mg/m<sup>3</sup>) were higher than the average upwind concentration (0.0008 mg/m<sup>3</sup>). The primary metals detected in the downwind samples from Site H were calcium and copper.

### 3.2.6 Source Area Groundwater Investigation

#### 3.2.6.1 Upgradient Groundwater Investigation

Existing wells EE-04 and EEG-108, renamed UGGW-EE-04 and UGGW-EE-108 for the SSP (with UGGW standing for Upgradient Groundwater), were used as background (upgradient) groundwater sampling locations for Sites G, H and L (Figure 3-7). The SHU and MHU sampling locations for UGGW-EE-04 were located approximately 900 feet upgradient of Site G, and about 75 feet upgradient of Site H. Access permission could not be obtained from the property owner to perform DHU push sampling at UGGW-EE-04 so a substitute location was selected (EE-04-SUB) approximately 1,600 feet upgradient of Site G (Figure 3-7). Sampling location UGGW-EE-108 was established approximately 750 feet upgradient of Site G, cross-gradient from Site H.

Existing well EE-20 (renamed UGGW-EE-20) was used as an upgradient groundwater sampling location for Site I (Figure 3-7). This background groundwater sampling location is approximately 75 feet upgradient of Site I North. One sample each was taken from the shallow, middle and deep hydrogeologic units at UGGW-EE-20.

UGGW-EE-04, UGGW-EE-108 and UGGW-EE-20 are screened at depths of 23 to 28 feet, 18 to 23 feet, and 24 to 29 feet in the SHU, respectively. Each existing well was redeveloped using the procedures stated in the FSR (Section 3.16) prior to background groundwater sampling in the SHU. Background groundwater samples were collected at depths of 60 feet below grade in the Middle Hydrogeologic Unit and 100 feet below grade in the Deep Hydrogeologic Unit at each of these locations using push-sampling technology (Geoprobe) and low-flow sampling techniques. A sampling depth of 60 feet is approximately the midpoint between the screened interval of the existing shallow wells and the bottom of the aquifer, which was anticipated to be approximately 100 feet deep. For discussion of the field procedures that were followed during sample collection and documentation related to the sampling of upgradient groundwater wells, refer to Section 3.16 (Volume 4) of the FSR.

A total of nine upgradient groundwater samples were collected. These samples were analyzed for VOCs, SVOCs, pesticides, herbicides, PCBs, dioxin and metals.

Table 3-89 presents the groundwater regulatory levels (i.e., MCLs or EPA Regional Screening Levels if MCLs are not available) for the chemical constituents that were analyzed during Sauget Area 1 groundwater investigations. Exceedances of regulatory levels are highlighted on the groundwater data summary tables, Tables 3-25 to 3-40, which are discussed in Sections 3.2.6, 3.3.1, and 3.3.2.

Summary statistics for upgradient groundwater analytical data are presented in Table 3-25 and maximum detected constituent concentrations are given below:

**Maximum Detected Constituent Concentrations in Groundwater Upgradient of the Sauget Area 1 Source Areas**

<u>Constituent</u>		<u>Maximum Detected Concentration</u> (ug/l)
VOCs	Benzene	6.55
	Carbon Disulfide	13.0
	Ethylbenzene	1.60
	Trichloroethene	0.57
	Xylenes, Total	11.0
SVOCs	Acenaphthene	8.0
	Benzo(a)anthracene	0.97
	Benzo(g,h,i)perylene	0.82
	Chrysene	1.3
	Dibenzofuran	0.36
	Diethylphthalate	0.35
	Fluorene	0.24
	Napthalene	9.9
	N-Nitrosodiphenylamine	0.25
Pesticides	delta-BHC	0.00675
	Endosulfan sulfate	0.001
	Endrin ketone	0.0021
	Gamma-BHC (Lindane)	0.00062
	Heptachlor	0.001
	Heptachlor epoxide	0.0016
Herbicides	2,4,5-T	0.210
	2,4,5-TP (Silvex)	0.160
Dioxin	Dioxin TEQ (Human Health)	0.000019
Target Metals	Copper	52.0
	Lead	22.0
	Nickel	175
	Zinc	1,000

Another potential source of contamination, the former Moss-American wood-preserving site, is located about ¼-mile east (upgradient) of Sauget Area 1. The former Moss-American site is not part of Sauget Area 1 (Ecology and Environment, 1998). Creosote, a common wood-preserved, contains PAHs.

A review of the groundwater data reveals that VOC and SVOC distributions are representative of the general extent of chemical constituents that are present above regulatory levels in Sauget Area 1. Consequently, discussion of background groundwater quality in the following paragraphs is limited to maximum detected concentrations of Total VOCs and Total SVOCs and their relation to constituent migration.

Total VOCs were not detected in the Shallow or Middle Hydrogeologic Units upgradient of Site G at background groundwater sampling location UGGW-EE-04. The maximum detected Total VOCs upgradient of Site G were in the Deep Hydrogeologic Unit at the farthest upgradient sampling location where benzene was detected at a concentration of 6.55 µg/L versus a Class I standard of 5 µg/L. The following table compares the maximum detected concentrations of Total VOCs at the Site G upgradient sampling locations with the maximum detected fill area concentrations.

TOTAL VOC CONCENTRATIONS UPGRADIENT OF SITE G (ug/L)			
	UGGW-EE-108	UGGW-EE-04	Maximum Detected Source Area Concentration
Upgradient Distance from Site G (Feet)	750	900 to 1,600	0
Shallow Hydrogeologic Unit	13	ND	19,153
Middle Hydrogeologic Unit	1.0	ND	145
Deep Hydrogeologic Unit	1.0	19	890

Total SVOCs were detected only in the Deep Hydrogeologic Unit at the farthest upgradient location, at concentrations higher than were detected at sampling locations 275 ft and 600 ft downgradient from Site G. Naphthalene was detected at a concentration of 100 µg/L, versus a Class I standard of 25 µg/L. The following table compares the concentrations of Total SVOCs at the upgradient sampling locations with the maximum detected fill area concentrations:

TOTAL SVOC CONCENTRATIONS UPGRADIENT OF SITE G (ug/L)			
	UGGW-EE-108	UGGW-EE-04	Maximum Detected Source Area Concentration
Upgradient Distance from Site G (Feet)	750	900 to 1,600	0
Shallow Hydrogeologic Unit	ND	ND	49,290
Middle Hydrogeologic Unit	ND	ND	14,957
Deep Hydrogeologic Unit	ND	101	3,013

As can be seen in the following table, Total VOCs were not detected in Site I upgradient groundwater sampling locations UGGW-EE-20:

TOTAL VOC CONCENTRATIONS UPGRADIENT OF SITE I (ug/L)		
	UPGW-EE-20	Maximum Detected Source Area Concentration
Upgradient Distance from Site I (Feet)	75	0
Shallow Hydrogeologic Unit	ND	4,835
Middle Hydrogeologic Unit	ND	14
Deep Hydrogeologic Unit	ND	163

Total SVOCs were detected in upgradient location UGGW-EE-20 at comparatively low concentrations but no detections were above Class I standards:

TOTAL SVOC CONCENTRATION UPGRADIENT OF SITE I (ug/L)		
	UPGW-EE-20	Maximum Detected Source Area Concentration
Upgradient Distance from Site I (Feet)	75	0
Shallow Hydrogeologic Unit	1.2	17,647
Middle Hydrogeologic Unit	2.3	363
Deep Hydrogeologic Unit	8.0	1,415

### 3.2.6.2 Shallow Hydrogeologic Unit Groundwater Sampling

Groundwater concentrations in the Shallow Hydrogeologic Unit at Sites G, H, I and L were evaluated by sampling existing wells EE-01 through EE-05, EE-12 through EE-15, EE-20, and EEG-101 through EEG-112 (Figures 3-7). Each of these Ecology and Environment wells was located, checked for the presence of non-aqueous phase liquids (NAPLs), plumbed for depth and matched against construction records,



redeveloped to remove accumulated fine-grained materials and promote ground water entry into the well, and sampled to provide data on current groundwater conditions in the SHU. A summary of the wells sampled and the corresponding disposal areas that the samples were collected for is provided below:

**Existing Source Area Groundwater Monitoring Wells Completed in the Shallow Hydrogeologic Unit**

<u>Disposal Area</u>	<u>Existing Well</u>	<u>Screen Depth</u>
Site G	EE-05	18 to 23
	EEG-101	18 to 23
	EEG-102	16.5 to 21.5
	EEG-104	19 to 24
	EEG-106	18 to 23
	EEG-107	23 to 28
	EEG-111 <sup>(1)</sup>	No Construction Log
	EEG-112	21 to 26
Site H	EE-01	28 to 23
	EE-02 <sup>(1)</sup>	18 to 23
	EE-03	27 to 32
	EEG-110	18 to 23
Site I South	EE-12 <sup>(2)</sup>	28 to 33
	EE-14 <sup>(1)</sup>	32.5 to 37.5
	EE-15 <sup>(2)</sup>	24 to 29
Site I North	EE-13 <sup>(2)</sup>	23 to 29
Site L	EEG-103 <sup>(2)</sup>	16.5 to 21.5
	EEG-105 <sup>(1)</sup>	No Construction Log
	EEG-109	17.5 to 22.5

- Notes:
- 1) Well could not be sampled; groundwater sample collected with Geoprobe
  - 2) Well no longer exists; groundwater sample collected with Geoprobe
  - 3) Well EEG-109 is the only existing well at Site L; EEG-103 and EEG-109 are located south of Site L
  - 4) A total of 19 existing source area wells were sampled for the SSP

Generally, samples were obtained from wells with screen intervals less than 30 feet below grade (i.e. in the SHU). One location, EE-14 was screened to a depth of 38 feet; however, this is still believed to be within the fill material of Site I South. In accordance with the approved work plan, no groundwater samples were collected beneath Site N although test trenching for the SSP revealed the presence of crushed or partially crushed drums, drum fragments and waste materials within that area. For wells that no longer existed or could not be sampled, samples were collected by advancing a Geoprobe and obtaining a groundwater sample from the same depth interval screened by the former well. Geoprobe samples were identified by the suffix "GP". Thus, the nomenclature for the disposal area groundwater sampling results was either the corresponding well number where the sample was collected, or the well number followed by the symbol GP. EEG-111 was described in the Support Sampling Plan as "South of Site G," so it was grouped with the Site G data. A discussion of the field procedures that were used while collecting these samples is provided in Section 3.7.3 of the FSR (Volume 1), which also contains all of the corresponding documentation (chain-of-custody forms, logs, meeting records, etc.). Each of the samples collected from the SHU at Sites G, H, I and L was analyzed for VOCs, SVOCs, pesticides, herbicides, PCBs, dioxin and metals.

### **3.2.6.3 Middle and Deep Hydrogeologic Units Groundwater Sampling**

Groundwater samples were collected in the MHU and DHU beneath Site H and Site I South at shallow groundwater concentration highs identified by Ecology and Environment (Ecology and Environment, 1998) in order to evaluate the vertical extent of organic and inorganic constituents underlying these source areas (Figure 3-7). Prior to collecting these push samples, telescoping surface casing was installed to approximate depths of five feet and 20 feet below the fill material at each site in order to exclude waste materials from the borehole and minimize carry-down of site-related constituents during groundwater sample collection. Surface casings were grouted from the bottom up after completion of sampling. Groundwater samples were collected every 10 feet from the bottom of the surface casing to bedrock, which were approximately 44 and 105 feet below existing grade at Site H and approximately 48 and 104 feet below existing grade at Site I South, respectively. For discussion of the field procedures that were followed during sample collection and documentation related to the alluvial aquifer ground-water sampling, refer to Section 3.8 (Volume 2) of the FSR. Eleven groundwater samples were collected in the MHU and DHU at Site H and Site I using push-sampling and a peristaltic pump. Samples were analyzed for VOCs, SVOCs, pesticides, herbicides, PCBs, dioxin and metals.

### **3.2.6.4 Alluvial Aquifer/Bedrock Interface Groundwater Sampling**

To evaluate the vertical extent of organic and inorganic constituents at the alluvial aquifer/bedrock interface, three monitoring wells were installed in the upper, weathered portion of the bedrock below the alluvial aquifer/bedrock interface at Sites G, H, and I South (Figure 3-7). Locations for these wells were based on shallow groundwater concentration highs identified by Ecology and Environment (Ecology and Environment, 1998). Telescoping surface casings were installed to the top of bedrock in order to minimize carry-down of site-related constituents during well installation and to prevent vertical migration of site-related constituents after completion. Bedrock was cored to a depth of 20 feet below the telescoping casing. Cores were digitally photographed in color against a scale and evaluated for porosity by examination in petrographic thin sections. Groundwater samples were collected from the open core holes in the bedrock below the telescoping casing. For discussion of the field procedures that were followed during sample collection and documentation related to the ground-water sampling of the alluvial aquifer/bedrock interface, refer to Section 3.10 (Volume 2) of the FSR. Three groundwater samples were collected in all, one from each of the wells (BR-G, BR-H and BR-I) completed in weathered bedrock at Sites G, H and I South. These samples were analyzed for VOCs, SVOCs, pesticides, herbicides, PCBs, dioxin and metals.

### **3.2.6.5 Source Area Groundwater Investigation Results**

Summary statistics (minimum, average and maximum concentrations) for constituents detected in groundwater within and below Sites G, H and I South are presented in Tables 3-26 to 3-28A. Because VOCs and SVOCs are good indicators of contaminant transport at the Sauget Area 1 source areas, the following discussion of groundwater within and beneath Sites G, H, I South, I North, and L focuses on these two parameter groups.

**VOCs in Source Area Groundwater** - Frequency of detection and maximum concentrations of the VOCs detected in groundwater at Sites G, H and I South are summarized in the following table. No VOCs were detected in shallow groundwater at Site I North at sampling location EE-13-GP.

**Frequency of Detection (FOD) and Maximum Detected Concentration of VOCs in Groundwater at Sites G, H and I South**

Constituent	Site G		Site H		Site I South	
	FOD (%)	Maximum Concentration (ug/l)	FOD (%)	Maximum Concentration (ug/l)	FOD (%)	Maximum Concentration (ug/l)
Acetone	50	590	11	490	ND	ND
Benzene	100	3,700	78	2,250	57	750
Chlorobenzene	100	4,300	100	4,350	57	3,800
Chloroform	ND	ND	33	425	ND	ND
1,1-Dichloroethene	ND	ND	11	3.7	ND	ND
1,2-Dichloroethene	ND	ND	33	17	14	160
Ethylbenzene	50	32	67	1,800	43	83
4-Methyl-2-Pentanone	50	1,300	11	26	ND	ND
Tetrachloroethene	50	170	ND	ND	ND	ND
Toluene	100	8,500	89	1,550	43	42
1,1,2,2-Trichloroethane	ND	ND	11	12	ND	ND
Trichloroethene	100	200	33	49.5	ND	ND
Vinyl Chloride	50	41	ND	ND	ND	ND
Xylenes, Total	50	130	67	200	29	18

Ten VOCs were detected in groundwater within or beneath Site G, twelve at Site H and six at Site I South. Frequently detected VOCs (FOD  $\geq$  50% at two or more sites) include benzene (3,700 ug/l maximum detected concentration at Site G), chlorobenzene (4,350 ug/l maximum detected concentration at Site H), ethylbenzene (1,800 ug/l maximum detected concentration at Site H), toluene (8,500 ug/l maximum detected concentration at Site G) and xylene (200 ug/l maximum detected concentration at Site H). Based on frequency of detection and maximum detected concentrations, Sites G and H are the primary source areas for VOCs in groundwater at Sauget Area 1. That said, chlorobenzene is frequently detected in groundwater within and beneath Site I South at concentrations up to 3,800 ug/l so this site is also a source area for VOCs in groundwater at Sauget Area 1. At Site L, a total of seven VOCs were detected in shallow groundwater at existing well EEG-109: benzene (44 ug/l), chlorobenzene (2.8 ug/l), chloroform (76 ug/l), dichloromethane (3.6 ug/l), 4-methyl-2-pentanone (50 ug/l), trichloroethene (1.6 ug/l) and xylene (3.8 ug/l). While a number of VOCs are present in groundwater in the SHU at Site L, their concentrations range from 2.8 to 76 ug/l indicating that this site is not likely to be a significant source area.

Given its high frequency of detection (50 to 100%) and high maximum detected concentrations (3,800 to 4,350 ug/l) at Sites G, H and I South, chlorobenzene would be a good indicator of any downgradient migration from these source areas.

**SVOCs in Source Area Groundwater** - Frequency of detection and maximum concentrations of the SVOCs detected in groundwater within or below Sites G, H and I South are summarized in the following table. No SVOCs were detected in shallow groundwater at Site I North at sampling location EE-13-GP.

Frequency of Detection (FOD) and Maximum Detected Concentration of SVOCs in Groundwater at Sites G, H and I South

Constituent	Site G		Site H		Site I South	
	FOD (%)	Maximum Concentration (ug/l)	FOD (%)	Maximum Concentration (ug/l)	FOD (%)	Maximum Concentration (ug/l)
Acenaphthene	ND	ND	11	2.2	14	2.1
Benzo(a)anthracene	ND	ND	ND	ND	14	2.3
Benzo(a)pyrene	ND	ND	ND	ND	29	3.4
Benzo(b)fluoranthene	ND	ND	ND	ND	29	3.8
Benzo(g,h,i)perylene	ND	ND	ND	ND	14	3.0
Benzo(k)fluoranthene	ND	ND	ND	ND	14	4.0
Bis(2-ethylhexyl)phthalate	ND	ND	67	32	100	3.8
Butylbenzylphthalate	ND	ND	ND	ND	29	10
Carbazole	ND	ND	44	5.2	29	26
4-Chloro-3-Methylphenol	ND	ND	11	1	ND	ND
4-Chloroaniline	100	23,000	67	1,800	29	1,800
2-Chloronaphthalene	ND	ND	11	12	ND	ND
2-Chlorophenol	100	630	67	73	29	27
Chrysene	ND	ND	ND	ND	14	3.1
Dibenzo(a,h)anthracene	ND	ND	ND	ND	14	3.0
Dibenzofuran	ND	ND	22	1.1	ND	ND
1,2-Dichlorobenzene	100	300	100	720	43	500
1,3-Dichlorobenzene	50	1.9	78	140	71	51.5
1,4-Dichlorobenzene	100	850	100	14,000	100	14,000
2,4-Dichlorophenol	100	3,600	78	370	14	3.8
Diethylphthalate	50	7.1	22	21	ND	ND
Dimethylphthalate	ND	ND	11	3.65	ND	ND
Di-n-butylphthalate	ND	ND	44	0.52	57	1.4
Di-n-octylphthalate	ND	ND	11	0.39	14	2.4
4,6-Dinitro-2-Methylphenol	ND	ND	11	14	ND	ND
Fluoranthene	ND	ND	ND	ND	14	0.41
Fluorene	ND	ND	78	30	ND	ND
Hexachlorobenzene	ND	ND	44	21	ND	ND
Indeno(1,2,3-cd)pyrene	ND	ND	ND	ND	14	0.92
Isophorone	ND	ND	11	0.75	ND	ND
2-Methylnapthalene	ND	ND	22	8	29	5.6
2-Methylphenol	100	230	22	30	29	21
3/4-Methylphenol	100	2,400	44	215	29	110
Naphthalene	100	2,100	44	2,300	57	1,400
2-Nitroaniline	ND	ND	11	13.5	ND	ND
Nitrobenzene	ND	ND	11	56.5	ND	ND
N-Nitrosodiphenylamine	ND	ND	11	7.6	14	23
Pentachlorophenol	50	2,000	100	4,300	50	500
Phenanthrene	ND	ND	22	4.8	ND	ND
Phenol	100	14,000	33	315	43	19
1,2,4-Trichlorobenzene	100	180	89	2,500	29	510
2,4,5-Trichlorophenol	ND	ND	67	190	14	1.6
2,4,6-Trichlorophenol	ND	ND	67	465	14	15

A total of 43 SVOCs were detected in groundwater within or beneath Sites G, H or I South but only ten SVOCs have a frequency of detection greater than or equal to 50 percent at two or more of the three sites: bis(2-ethylhexyl)phthalate (32 ug/l maximum detected concentration at Site H); 4-chloroaniline (23,000 ug/l maximum detected concentration at Site G); 2-chlorophenol (630 ug/l maximum detected concentration at Site G); 1,2-dichlorobenzene (720 ug/l maximum detected concentration at Site H); 1,3-dichlorobenzene (140 ug/l maximum detected concentration at Site H); 1,4-dichlorobenzene (14,000 ug/l maximum detected concentration at Site H); 2,4-dichlorophenol (3,600 ug/l maximum detected concentration at Site G); naphthalene (2,300 ug/l maximum detected concentration at Site H);

pentachlorophenol (4,300 ug/l maximum detected concentration at Site H); and 1,2,4-trichlorobenzene (2,500 ug/l maximum detected concentration at Site H). Of these ten SVOCs, seven of the maximum detected concentrations were found at Site H bis(2-ethylhexyl)phthalate; 1,2-dichlorobenzene; 1,3-dichlorobenzene; 1,4-dichlorobenzene; naphthalene; pentachlorophenol; and 1,2,4-trichlorobenzene], indicating that this site is the primary source area for SVOCs in Sauget Area 1. Three of the maximum detected concentrations of SVOCs with a high frequency of detection were found at Site G: 4-chloroaniline, 2-chlorophenol and 2,4-dichlorophenol. 1,4-Dichlorobenzene and naphthalene were the only two SVOCs at Site I South with a frequency of detection equal to or greater than 50 percent (88 and 50%, respectively) and a high maximum detected concentration (14,000 and 1,400 ug/l, respectively).

At Site L, five SVOCs were detected in existing well EEG-109 screened in the SHU: 4-chloroaniline (55 ug/l); 2-chlorophenol (21 ug/l); 2,4-dichlorophenol (26 ug/l); 3/4-methylphenol (5.5 ug/l); and naphthalene (28 ug/l). With maximum detected SVOC concentrations in SHU groundwater ranging from 5.5 to 28 ug/l, Site L is not a significant source area.

Based on high frequency of detection (greater than or equal to 50 percent at two or more sites) and high maximum detected concentrations, 4-chloroaniline (23,000 ug/l maximum detected concentration at Site G) and 1,4-dichlorobenzene (14,000 ug/l maximum detected concentration at Sites H and I South) would be good indicators of any downgradient migration from Sites G, H and I South.

**Vertical Distribution of VOCs and SVOCs in Source Area Groundwater** - Total VOCs and Total SVOCs, which are good indicators of contaminant transport, were detected throughout the saturated zone beneath Sites G, H and I South as shown below:

<u>Disposal Area</u>	<u>Hydrogeologic Unit</u>	<u>Total VOCs (ug/L)</u>	<u>Total SVOCs (ug/L)</u>
Site G	SHU	19,153	49,290
	MHU	NS	NS
	DHU	NS	NS
	Weathered Bedrock	247	10,468
Site H	SHU	8,250	11,978
	MHU	145	14,957
	DHU	890	3,013
	Weathered Bedrock	225	661
Site I South	SHU	4,835	17,647
	MHU	14	363
	DHU	163	1,415
	Weathered Bedrock	797	1,271,950

With the exception of Total SVOCs at Site H, concentrations of Total VOCs and Total SVOCs at Sites G, H and I South are one to two orders of magnitude higher in the SHU than in the underlying MHU and DHU. Observed high Total VOC and Total SVOC concentrations in the SHU at Sites G, H and I South are most likely the result of inhomogeneous waste materials, which range from industrial wastes to construction debris, and low-permeability backfill within the disposal areas, and low-permeability silty sands in the SHU beneath these sites, all of which can retard leaching and transport of contaminants to the underlying MHU and DHU.

Waste materials were originally deposited in the Sauget Area 1 disposal areas during a period of time when groundwater levels in the American Bottoms alluvial aquifer were significantly lower compared to current levels due to extensive industrial groundwater withdrawal. Base elevations of the disposal areas are located within the SHU, and in some cases may extend into the MHU. Leaching of constituents from wastes in the disposal areas represents a historic source of impact to ground water and a potential ongoing source in the future.

Section 6.2 of this report summarizes result of mass flux estimates that were developed for Site I (GSI, 2005). Results indicate that the estimated mass flux of chlorobenzene, 1,4-dichlorobenzene, and benzene due to leaching of unsaturated source materials is small compared to estimated mass flux of these three COCs by lateral groundwater flow in the MHU and DHU beneath the Site I source area.

Dense non-aqueous phase liquid (DNAPL) waste materials disposed in the Sauget Area 1 source areas may have migrated vertically into the alluvial aquifer matrix. A second potential continuing source of groundwater impact in Sauget Area 1 is dissolution of liquid waste that migrated vertically from the disposal areas before becoming trapped by capillary forces in pore spaces within the aquifer matrix (residual DNAPL) and/or accumulating at the alluvial aquifer/bedrock interface (pooled DNAPL).

Typically, the majority of DNAPL mass migrating from a source area is trapped by capillary forces within the alluvial aquifer pore space in small, discrete blobs and ganglia as residual DNAPL. Residual DNAPL is not believed to be mobile, and is expected to dissolve relatively slowly. As stated by Pankow and Cherry (1996), "Once the release of liquid waste into the subsurface ceases, subsurface movement of DNAPL also ceases soon thereafter, perhaps within weeks or months...". With industrial disposal ceasing in 1957 at Sites H and I South and in 1966 at Site G, residual DNAPL at these sites is not likely to be mobile.

The potential for DNAPL occurrence at Sauget Area 1 is based on several indicators: 1) some constituent concentrations increase with depth, 2) constituents are found deep in the aquifer, and 3) some constituents are present at concentrations in excess of 1% of the pure-phase water solubility limit. Results of the USEPA Quick Reference Fact Sheet *Estimating Potential for Occurrence of DNAPL at Superfund Sites* indicate a "high-moderate" potential for DNAPL (USEPA, 1992).

Where DNAPL migration has occurred, most of the mass is expected to be trapped throughout the alluvial aquifer matrix as discrete small blobs and ganglia that are held tightly in the porous alluvial aquifer media by capillary forces (residual DNAPL). Where sufficient quantities were disposed in the fill areas, some DNAPL may have migrated to the bedrock surface and pooled. The slow dissolution of DNAPL trapped in the alluvial aquifer matrix or pooled at the bedrock surface represents a potential source of ongoing impact to ground water.

An extensive DNAPL characterization and remediation study was performed at Sauget Area 1 in 2004-2005 to characterize the extent of residual and pooled DNAPL (GSI, 2006c). Results of the DNAPL characterization and remediation study are summarized in Sections 4.2 and 5.2.4 of this report.

Dissolution of residual and/or pooled DNAPL is a likely ongoing source of impacted groundwater at Sites G, H and I South. Dissolution of residual DNAPL is the likely cause of the observed Total SVOC concentration in the MHU at Site H, which is 24.9% higher than the concentration in the overlying SHU. Pooled DNAPL is the likely cause of the 1,271,950 ug/L Total SVOC observed in weathered bedrock beneath Site I South. VOCs and SVOCs detected in Site I South weathered bedrock monitoring well BR-I are listed below:

**VOC and SVOC Concentrations Detected in Weathered Bedrock at Site I South**

<u>Analytes</u>	<u>Constituent</u>	<u>Concentration</u> (ug/l)	<u>Analytes</u>	<u>Constituent</u>	<u>Concentration</u> (ug/l)
VOCs	Benzene	63	SVOCs	Acenaphthene	130
	Chlorobenzene	240		Anthracene	130
	Ethylbenzene	390		Benzo(a)anthracene	400
	Trichloroethene	3.7		Benzo(a)pyrene	380
	Xylenes, Total	36		Benzo(b)fluoranthene	290
				Benzo(g,h,i)perylene	300
				Benzo(k)fluoranthene	220
				Bis(2-ethylhexyl)phthalate	420
				Butylbenzylphthalate	160
				Carbazole	240
				Chrysene	740
				1,2-Dichlorobenzene	12,000
				1,3-Dichlorobenzene	1,100
				1,4-Dichlorobenzene	51,000
				2,4-Dichlorophenol	2,400
				Di-n-butylphthalate	300
				Di-n-octylphthalate	180
				Dibenzo(a,h)anthracene	210
				Fluoranthene	170
				Fluorene	360
				Hexachlorobenzene	90,000
				Indeno(1,2,3-cd)pyrene	240
				2-Methylnaphthalene	670
				N-nitrosodiphenylamine	760
				Naphthalene	5,800
				Nitrobenzene	140
				Phenanthrene	790
				Phenol	180
				Pyrene	540
				1,2,4-Trichlorobenzene	1,100,000
				2,4,6-Trichlorophenol	1,700

### 3.3 Downgradient Groundwater Investigation

#### 3.3.1 Downgradient Groundwater Investigation Sampling

##### 3.3.1.1 Groundwater Sampling Downgradient of Source Areas

Groundwater quality downgradient of the disposal areas was investigated by collecting groundwater samples along two sampling transects, one downgradient of Site I South (Figure 3-7) and another downgradient of Sites G, H and L (Figure 3-7). Horizontal and vertical extent of organic and inorganic constituents in groundwater downgradient of these source areas were evaluated by collecting samples at three sampling stations located along a transect between the maximum shallow-groundwater concentrations observed by Ecology and Environment (1998) and Illinois Route 3. These sampling stations are listed below:

<b>Sampling Stations Downgradient of Site I South</b>	<b>Sampling Stations Downgradient of Sites G, H and L</b>
<b>AA-I-S1</b>	<b>AA-GHL-S1</b>
<b>AA-I-S2</b>	<b>AA-GHL-S2</b>
<b>AA-I-S3</b>	<b>AA-GHL-S3</b>

Stations with the S1 suffix are closest to the disposal areas, and stations with the S3 suffix are farthest from the disposal areas. Groundwater samples were collected from the SHU, MHU, and the DHU. Sample collection began at the water table and continued every ten feet until bedrock was encountered.

A total of 28 groundwater samples were collected downgradient of Site I South and 31 samples were collected downgradient of Sites G, H and L. Samples were analyzed for VOCs, SVOCs, pesticides, herbicides, PCBs and metals. The presence or absence of dioxin in ground water downgradient from Site I South and Sites G, H and L was evaluated by analyzing samples from the SHU, MHU and DHU downgradient of each of these source areas. A total of 18 samples were collected and analyzed for dioxins via USEPA Method 8290. Samples were collected concurrently with the other downgradient samples described above.

For discussion of the field procedures that were followed during sample collection and documentation related to the downgradient alluvial aquifer ground-water sampling, refer to Section 3.9 (Volume 2) of the FSR.

#### **3.3.1.2 Groundwater Sampling Downgradient of Creek Segment B**

Groundwater samples were collected every ten feet from the water table to bedrock at three sampling stations located approximately 300 to 450 feet downgradient of Creek Segment B between Site G and Judith Lane (Figure 3-7). Thirty samples were collected and analyzed in an off-site laboratory for VOCs, SVOCs, pesticides, herbicides, PCBs and metals. The presence or absence of dioxin in groundwater was evaluated by analyzing a total of nine samples from the Shallow, Middle and Deep Hydrogeologic Units, three samples from each unit.

#### **3.3.1.3 Groundwater Sampling in Residential Areas**

Shallow groundwater in residential areas bordering Creek Segment B was sampled during the SSP investigation to evaluate potential transport of constituents from creek sediments and floodplain soils to groundwater. This sampling program included four non-potable domestic wells (100 Judith Lane, 102 Judith Lane, 104 Judith Lane, and 109 Judith Lane – see Figure 2-27) and vertical profiling (15, 20 and 40 ft. bgs) at the west end of Walnut Street and the east bank of Creek Segment B just north of Judith Lane (Figure 3-7). After collection and analysis of the vertical-profile shallow-groundwater samples at Walnut Street and Judith Lane, one MicroWell<sup>®</sup> was installed at each sampling station with its screened interval in the zone of highest detected constituent concentrations (approximately 40 feet below ground surface). These wells were continuously pumped for 24 hours using a peristaltic pump in order to stress the saturated zone during sampling. Time-series samples were collected at approximately 0, 12, and 24 hours after the start of pumping to evaluate constituent concentration trends over time. For discussions of the field procedures that were followed during sample collection and documentation related to the domestic well sampling, vertical profiling and times-series sampling, refer to Sections 3.13, 3.11 and 3.12



(Volume 3) of the FSR, respectively.

### 3.3.2 Downgradient Groundwater Investigation Results

Groundwater flowing beneath Sauget Area 1 ultimately discharges to the Mississippi River, approximately 5,700 feet downgradient of its western boundary. Groundwater in the alluvial aquifer underlying Sauget Area 1 flows west and northwest toward the Mississippi River at an estimated velocity of 29.6 feet/year in the SHU and 296 feet/year in the MHU/DHU (assuming a porosity of 0.35). Groundwater is the most important migration pathway from the Sauget Area 1 source areas because it has the potential to discharge site-related constituents to the Mississippi River. Potential impact could result from groundwater discharge into the river if the constituents detected in groundwater downgradient of the Sauget Area 1 source areas migrate that far.

Review of groundwater data collected during the SSP revealed that the distributions of VOCs and SVOCs downgradient of Site I South and Sites G, H and L were representative of the extent of chemical constituents present above regulatory levels. Generally speaking, herbicide and pesticide distributions parallel the VOC and SVOC data.

Concentrations of PCBs, dioxin TEQs and metals occur sporadically and at comparatively low concentrations both upgradient and downgradient of disposal areas, throughout the aquifer saturated thickness. There were no detections of PCBs at the upgradient groundwater sampling locations. Concentrations of PCBs exceeding regulatory levels were detected downgradient of the Sites G, H, and L and Site I South source areas (see Tables 3-29 and 3-30). Concentrations of Dioxin-TEQ were below regulatory levels both upgradient and downgradient of the disposal areas.

A total of 7 metals were detected in one or more upgradient groundwater samples at concentrations exceeding regulatory levels (see Table 3-25). A total of 12 metals were detected in one or more groundwater samples from downgradient of Site I South at concentrations exceeding regulatory levels (see Table 3-29), and a total of 8 metals were detected in one or more groundwater samples from downgradient of Sites G, H, and L at concentrations exceeding regulatory levels (see Table 3-30).

Discussion of the downgradient groundwater investigation is limited to maximum detected concentrations of VOCs and SVOCs because VOCs and SVOCs were representative of the extent of chemical constituents present above regulatory levels.

#### 3.3.2.1 Groundwater Downgradient of Site I South

**VOCs in Downgradient Groundwater** - As shown in Table 3-29 and summarized below, VOCs were present in the SHU, MHU and DHU downgradient of Site I South:

MAXIMUM DETECTED TOTAL VOC CONCENTRATIONS DOWNGRADIENT OF SITE I SOUTH (ug/L)			
Sampling Station	AA-I-S1	AA-I-S2	AA-I-S3
Distance from Source Area	100 ft.	650 ft.	1,200 ft.
Shallow Hydrogeologic Unit	9,230	4,230	ND
Middle Hydrogeologic Unit	20,276	19,300	2,314
Deep Hydrogeologic Unit	34,140	11,120	5,677

Total VOCs extended throughout the saturated zone downgradient of Site I South to the last sampling station (AA-I-3), which was located just east of Mississippi Avenue (Route 3). Compared to concentrations in AA-I-S1, maximum detected Total VOC concentrations in AA-I-S3 decreased to none detected in the Shallow Hydrogeologic Unit, and decreased by nearly an order of magnitude in the Middle and Deep Hydrogeologic Units. Maximum detected Total VOC concentrations were found in the MHU and DHU, which is consistent with dissolution of residual and pooled DNAPL resulting from past vertical migration of liquid waste from this disposal area into the underlying MHU and DHU. As previously described, hydraulic conductivities in the MHU and DHU are higher than in the SHU and, therefore, mass flux is higher in these hydrogeologic units than in the SHU.

The VOCs most frequently detected downgradient of Site I South (Table 3-29) were chlorobenzene (97% FOD); benzene (86% FOD); ethylbenzene (41% FOD); 1,1-dichloroethane (38% FOD); 1,2-dichloroethene (38% FOD) and vinyl chloride (38% FOD). Tetrachloroethene (24% FOD) and trichloroethene (17% FOD) were also present in groundwater downgradient of Site I South.

Individual VOCs within each of the three hydrogeologic units at sampling location AA-I-S1, which is 100 feet downgradient from the boundary of Site I South, were compared to the standards for Illinois Class I Potable Resource Groundwater as defined in 35 IAC 620 and 35 IAC 742 Appendix B. Discrete interval samples exceeded standard in all three hydrogeologic units for benzene and chlorobenzene. These constituents were also detected above standard at downgradient location AA-I-S3. There were exceedances of other constituents in the Shallow and Middle hydrogeologic units, as summarized below:

**Maximum Detected VOC Concentrations Downgradient of Site I South that Exceeded Illinois Class I Groundwater Standards**

Constituents Detected Above Standard		Standard	SHU	MHU	DHU
VOCs, ug/L	Benzene	5	620	190	140
	Chlorobenzene	100	8,700	20,000	34,000
	1,1-Dichloroethane	700	960	NE	NE
	1,1-Dichloroethene	7	32	NE	NE
	1,2-Dichloroethene	170	1,200	310	NE
	Vinyl Chloride	2	970	320	NE

- Notes: 1) Groundwater samples collected 100 ft. downgradient of Site I South  
2) NE = No Exceedance

**SVOCs in Downgradient Groundwater** - SVOCs occurred within the SHU, MHU and DHU immediately downgradient of Site I South (Sampling Station AA-I-S1) and extended as far as 1,200 feet downgradient of this source area (Sampling Station AA-I-S3). The following table summarizes the maximum detected Total SVOC concentrations at Site I South downgradient sampling station locations AA-I-S1, AA-I-S2 AA-I-S3:

MAXIMUM DETECTED TOTAL SVOC CONCENTRATIONS DOWNGRADIENT OF SITE I SOUTH (ug/L)			
Sampling Station	AA-I-S1	AA-I-S2	AA-I-S3
Distance from Source Area	100 ft.	650 ft.	1,200 ft.
Shallow Hydrogeologic Unit	7,056	5,153	0.8
Middle Hydrogeologic Unit	12,054	5,544	1,777
Deep Hydrogeologic Unit	11,047	5,565	3,502

Total SVOC concentrations decreased with distance downgradient of Site I South in the SHU, MHU and DHU. Comparing maximum detected concentrations between AA-I-S1 and AA-I-S3, Total SVOC concentrations decreased by four orders of magnitude in the Shallow Hydrogeologic Unit, nearly one order of magnitude in the Middle Hydrogeologic Unit, and by a factor of slightly more than three in the Deep Hydrogeologic Unit.

The highest downgradient Total SVOC concentrations occurred in the MHU and DHU at sampling station AA-I-S1, which is located 100 feet downgradient of Site I South. These comparatively high concentrations of Total SVOCs are most likely due to dissolution and downgradient transport of DNAPL trapped in the alluvial aquifer matrix and/or pooled on bedrock beneath Site I South. Following vertical migration of liquid waste and/or leaching of dissolved constituents into the hydrogeologic units below Site I South, more constituent migration occurred in the MHU and DHU downgradient of the disposal area because their higher hydraulic conductivities resulted in a significantly higher mass flux.

1,4-Dichlorobenzene was the most frequently detected SVOC (Table 3-29) in groundwater downgradient of Site I South (90% FOD) followed by 4-chloroaniline (86% FOD); 1,2-dichlorobenzene (83% FOD), 1,3-dichlorobenzene (79% FOD); 2-chlorophenol (72% FOD); naphthalene (69% FOD); 2,4-dichlorophenol (48% FOD) and n-nitrosodiphenylamine (34% FOD). Frequency of detection of the remaining SVOCs detected in groundwater downgradient of Site I South ranged from 3 to 17% (Table 3-29).

Individual SVOCs within each of the three hydrogeologic units at sampling location AA-I-S1, which is 100 feet downgradient from the boundary of Site I South, were compared to the standards for Illinois Class I Potable Resource Groundwater as defined in 35 IAC 620 and 35 IAC 742 Appendix B. Discrete interval samples exceeded standard in all three hydrogeologic units for 1,4-dichlorobenzene, and in the Shallow and Middle Hydrogeologic Units for 4-chloroaniline. These constituents were also detected above standard in the Middle and Deep Hydrogeologic Units at the downgradient location AA-I-S3. There were exceedances of other SVOCs in the Middle and Deep Hydrogeologic Units at AA-I-S1, as summarized below:

**Maximum Detected SVOC Concentrations Downgradient of Site I South that Exceeded Illinois Class I Groundwater Standards**

Constituents Detected Above Standard		Standard	SHU	MHU	DHU
SVOCs, ug/L	1,4-Dichlorobenzene	75	4,400	10,000	9,700
	4-Chloroaniline	28	4,100	1,700	NE
	2-Chlorophenol	35	NE	39	52
	2,4-Dichlorophenol	21	NE	42	47
	1,2,4-Trichlorobenzene	70	NE	NE	2,700
	N-nitrosodiphenylamine	10	NE	28	18

- Notes: 1) Groundwater samples collected 100 ft. downgradient of Site I South  
2) NE = No Exceedance

### 3.3.2.2 Groundwater Downgradient of Sites G, H and L

**VOCs in Downgradient Groundwater** - The following table summarizes the maximum Total VOC concentrations detected downgradient of Sites G, H and L and Table 3-30 includes summary statistics (frequency of detection and minimum, mean and maximum detected concentrations):

MAXIMUM DETECTED TOTAL VOC CONCENTRATIONS DOWNGRADIANT OF SITES G, H and L (ug/L)			
Sampling Station	AA-GHL-S1	AA-GHL-S2	AA-GHL-S3
Distance from Source Area	25 ft.	275 ft.	600 ft.
Shallow Hydrogeologic Unit	13.5	3.5	ND
Middle Hydrogeologic Unit	270	131	8.8
Deep Hydrogeologic Unit	9.6	79	16

Total VOC concentrations in the SHU and MHU decreased consistently with distance downgradient of Sites G, H and L but the highest Total VOC concentration in the DHU occurred at Sampling Station AA-GHL-S2, which is 275 ft. downgradient of these source areas. The highest detected Total VOC concentrations at Sampling Stations AA-GHL-S1 (25 feet downgradient) and AA-GHL-S2 (275 feet downgradient) occurred in the MHU while the highest Total VOC concentration at Sampling Station AA-GHL-S3 was found in the DHU.

Table 3-30 gives the frequency of detection (FOD) and minimum, maximum and mean concentrations of the individual VOCs detected in groundwater downgradient of Sites G, H and L. Nine VOCs were detected in groundwater downgradient of Sites G, H and L and chlorobenzene was the most frequently detected VOC (70% FOD). Tetrachloroethene (17% FOD) and its breakdown products, trichloroethene (20% FOD), dichloroethane (37% FOD) and vinyl chloride (3% FOD), were also present in groundwater downgradient of these source areas. Toluene was detected with a frequency of 17%. The FOD for acetone and ethylbenzene was 3% while the FOD for benzene was 7%.

Individual VOCs within each of the three hydrogeologic units at sampling location AA-GHL-S1, which was located at the downgradient boundary of Site G, were compared to the standards for Illinois Class I Potable Resource Groundwater as defined in 35 IAC 620 and 35 IAC 742 Appendix B. Two discrete interval samples in the SHU exceeded the standard for tetrachloroethene with a maximum detected concentration of 13 ug/L versus the 5 ug/L Class I standard and one discrete interval sample within the MHU exceeded the chlorobenzene standard (270 ug/L versus 100 ug/L). Neither of these constituents was detected above standard at downgradient sampling location AA-GHL-S3.

**SVOCs in Downgradient Groundwater** - With the exception of the SHU at Sampling Station AA-GHL-S2, Total SVOCs were detected in all three hydrogeologic units downgradient of Sites G, H and L:

MAXIMUM DETECTED TOTAL SVOC CONCENTRATIONS DOWNGRADIANT OF SITES G, H and L (ug/L)			
Sampling Station	AA-GHL-S1	AA-GHL-S2	AA-GHL-S3
Distance from Source Area	25 ft.	275 ft.	600 ft.
Shallow Hydrogeologic Unit	2.4	ND	0.8
Middle Hydrogeologic Unit	38	32	2.9
Deep Hydrogeologic Unit	38	11.3	4.5

Total SVOC concentrations in the MHU and DHU consistently decreased with increasing distance from these source areas.

Nineteen SVOCs were detected in groundwater downgradient of Sites G, H and L with 1,2-dichlorobenzene (FOD 37%) and 1,4-dichlorobenzene (FOD 33%) the most frequently detected (Table 3-30). Other chlorobenzenes detected included 1,3-dichlorobenzene (FOD 7%) and 1,2,4-trichlorobenzene (FOD 3%). 2-Chlorophenol and 4-chloroaniline were detected at a frequency of 17% and 7%,

respectively. Two phthalates were detected with FODs of 10% and 20% and eleven PAHs were detected with FODs ranging from 3 to 10%.

Chrysene was the only organic constituent present at sampling location AA-GHL-S1, the first sampling location downgradient of Sites G, H and L, with a concentration higher in the DHU than the Class I Potable Resource Groundwater standard as defined in 35 IAC 620 and 35 IAC 742 Appendix B (2.4 ug/L versus 1.5 ug/L). There was one exceedance of a discrete sample interval for lead in the DHU at AA-GHL-S1 (0.01 mg/L versus a Class I standard of 0.0075 mg/L).

### 3.3.2.3 Groundwater Downgradient of Creek Segment B

During the SSP investigation, groundwater sampling was conducted at three stations along a north/south transect located approximately 300 feet south of Site G and approximately 300 to 500 feet west of Creek Segment B to determine whether constituents were present in a cross-gradient direction from the Sauget Area 1 disposal areas. With groundwater flow patterns now shown to be generally to the west and northwest, this objective is now moot. Nonetheless, these data can be used to evaluate impacted groundwater migration downgradient of Creek Segment B.

Groundwater samples were collected every ten feet from the water table to bedrock at three sampling stations located approximately 300 to 500 feet downgradient of Creek Segment B between Site G and Judith Lane (Figure 3-7). Thirty samples were collected and analyzed in an off-site laboratory for VOCs, SVOCs, pesticides, herbicides, PCBs and metals. The presence or absence of dioxin in groundwater was evaluated by analyzing a total of nine samples from the Shallow, Middle and Deep Hydrogeologic Units, three samples from each unit.

As discussed above, review of the groundwater data revealed that VOC and SVOC distributions were representative of general plume extent, especially concerning the extent of constituents that are present above regulatory levels. Consequently, discussion in the following paragraphs is limited to maximum detected concentrations of Total VOCs and Total SVOCs and their relation to constituent migration.

**VOCs in Downgradient Groundwater** - VOCs occurred in low concentrations in the SHU, MHU and DHU downgradient of Creek Segment B as shown in the following table of maximum detected Total VOC concentrations at sampling stations AA-SW-S1, AA-SW-S2 AND AA-SW-S3:

MAXIMUM DETECTED TOTAL VOC CONCENTRATIONS DOWNGRADIENT OF CS-B (ug/L)			
Sampling Station	AA-SW-S1	AA-SW-S2	AA-SW-S3
Distance from Dead Creek	440 ft.	440 ft.	320 ft.
Shallow Hydrogeologic Unit	28	ND	0.3
Middle Hydrogeologic Unit	16	12	38
Deep Hydrogeologic Unit	7.5	6.5	4.5

Table 3-31 summarizes the analytical results for the groundwater samples collected downgradient of Creek Segment B and frequency of detection and maximum concentration of individual VOCs are presented below:

**Maximum Detected Total VOC Concentrations in Groundwater Downgradient of Creek Segment B**

Constituent	Frequency of Detection (%)	Maximum Detected Concentration (ug/l)
VOCs		
Acetone	3	28
Benzene	9	3.3
Chlorobenzene	33	34
1,1-Dichloroethene	6	0.8
1,2-Dichloroethene	18	1.4
Toluene	12	0.99
Trichloroethene	15	0.75
Xylenes, Total	3	3.7

Individual VOCs within each of the three hydrogeologic units at each of the three sampling stations were compared to the standards for Illinois Class I Potable Resource Groundwater as defined in 35 IAC 620 and 35 IAC 742 Appendix B. No VOCs in excess of Class I standards were detected.

**SVOCs in Downgradient Groundwater** - SVOCs were detected sporadically at sampling stations AA-SW-S1, AA-SW-S2 AND AA-SW-S3 downgradient of Creek Segment B as shown in the following table of maximum Total SVOC concentrations in the SHU, MHU and DHU and summarized in Table 3-31:

MAXIMUM DETECTED TOTAL SVOC CONCENTRATIONS DOWNGRADIENT OF CS-B (ug/L)			
Sampling Station	AA-SW-S1	AA-SW-S2	AA-SW-S3
Distance from Dead Creek	440 ft.	440 ft.	320 ft.
Shallow Hydrogeologic Unit	0.4	ND	0.3
Middle Hydrogeologic Unit	11	16	7.1
Deep Hydrogeologic Unit	5.5	1.8	0.9

Eight SVOCs were detected in groundwater downgradient of Creek Segment B with frequency of detections ranging from 3 to 27%:

**Maximum Detected Constituent Concentrations in Groundwater Downgradient of Creek Segment B**

Constituent	Frequency of Detection (%)	Maximum Detected Concentration (ug/l)
SVOCs		
2-Chlorophenol	3	0.25
4-Chloroaniline	6	5.3
1,2-Dichlorobenzene	27	5.8
1,4-Dichlorobenzene	27	11
Diethylphthalate	6	0.49
Di-n-butylphthalate	9	0.43
Pentachlorophenol	15	1.40
Phenanthrene	3	0.42

Individual SVOCs within each of the three hydrogeologic units at all three sampling stations downgradient of Creek Segment B were compared to the standards for Illinois Class I Potable Resource Groundwater as defined in 35 IAC 620 and 35 IAC 742 Appendix B. Pentachlorophenol, with a maximum detected concentration of pentachlorophenol of 1.4 ug/l, was the only SVOC present in groundwater downgradient of Creek Segment B at concentrations higher than the Illinois Class I Groundwater Remediation Objective of 1.0 ug/l.

#### 3.3.2.4 Groundwater in Residential Areas

Residential-area shallow groundwater samples were analyzed for VOCs, SVOCs, pesticides, herbicides, PCBs, dioxin and metals. The well locations are shown on Figure 2-27. Summary statistics (minimum, mean and maximum detected concentrations) for the non-potable domestic well samples are presented in Table 3-32. Walnut Street shallow groundwater sampling results are summarized in Table 3-33 and the time-series sampling results are given in Table 3-34 (0 Hour), Table 3-35 (12 Hour) and Table 3-36 (24 Hour). Judith Lane shallow groundwater sampling results are summarized in Table 3-37 and the time-series sampling results are given in Table 3-38 (0 Hour), Table 3-39 (12 Hour) and Table 3-40 (24 Hour).

The maximum concentration of total VOCs detected during these sampling programs was 1.5 µg/L in the non-potable residential well at 102 Judith Lane. Maximum detected concentration of total SVOCs was 6.7 µg/L at time-series groundwater sampling location TS-S1 at Walnut Street after 24 hours of pumping. Some of these SVOCs included concentrations above Class I standards.

Pesticides were detected at a maximum concentration of 0.004 µg/L in the non-potable residential well at 100 Judith Lane. Total pesticides were initially detected at 0.04 µg/L at one of the time-series sampling locations; however, no pesticides were detected during subsequent time-series sampling events. All of the pesticide detections were below regulatory levels. Herbicides were not detected in any of the non-potable domestic wells. The maximum concentration of total herbicides detected at the time-series sampling locations was 0.66 µg/L at the 15-foot depth interval at Judith Lane (SGW-2). All of the herbicide detections were below regulatory levels.

No PCBs were detected in any of the domestic wells. PCBs were initially detected at 0.06 µg/L, below regulatory levels, at the 40-foot sampling interval at location SGW-S1; however, no PCBs were detected during subsequent time-series sampling at this location.

Dioxin TEQs were measured in all non-potable domestic wells at concentrations ranging from 3 ppq to 6 ppq. Dioxin TEQs measured in initial samples collected from the time-series sampling locations ranged from 0.014 ppq to 77 ppq, and the 77 ppq detection exceeded the regulatory level. However, concentrations measured during subsequent time-series sampling under pumping conditions were all below 15 ppq, and below the regulatory level.

Arsenic, iron, lead, and manganese were detected in samples from the non-potable domestic wells at concentrations exceeding regulatory levels. Aluminum, arsenic, cobalt, iron, lead, and manganese were detected at concentrations above regulatory levels in initial samples from Walnut Street shallow groundwater, but during time-series sampling under pumping conditions the only metals exceeding regulatory levels were arsenic, iron, and manganese. Aluminum, iron, and manganese were detected at concentrations above regulatory levels in initial samples from Judith Lane shallow groundwater, but during time-series sampling under pumping conditions the only metals exceeding regulatory levels were iron and manganese.

### **3.4 Surface Water and Sediment Investigation**

#### **3.4.1 Surface Water Investigation**

##### **3.4.1.1 Surface Water Investigation Locations**

Surface-water sampling was conducted at Dead Creek, Site M, the Borrow Pit Lake, Prairie du Pont Creek and two reference areas during baseflow conditions to determine the downstream concentrations of site-related constituents and to provide information for use in the HHRA and the ERA. Surface-water sampling locations, which are described below, are shown on Figure 3-8:

- Surface-water samples were collected at the approximate upper, middle, and lower sections of each segment of Dead Creek (Creek Segments B, C, D, E and F) to evaluate the downstream extent of site-related constituents. Additionally, one surface water sample was collected at Site M.
- Two surface-water samples were collected in Borrow Pit Lake upstream of the discharge of Dead Creek to assess the effect of backwater conditions and/or the contributions of other sources.
- One surface-water sample was collected upstream and one sample was collected downstream of the confluence of Dead Creek and Prairie du Pont Creek.
- Two surface-water samples were collected at two sampling stations located at Reference Areas 1 and 2.

The ERA (Menzie-Cura, 2001) includes descriptions, maps, and photos of Reference Areas 1 and 2. The reference areas were selected based on the following criteria: i) physical similarity to Dead Creek or Borrow Pit Lake; and ii) location away from direct influence of industrial discharges, including major highways. The selected location for Reference Area 1 was a section of Old Prairie du Pont Creek near the town of East Carondelet, Illinois, approximately three miles southwest of the end of Dead Creek in the Borrow Pit Lake. This section of Old Prairie du Pont Creek is a broad shallow water body with a mud substrate similar to the Borrow Pit Lake. It was distant from any influence from Sauget Area 1 or other industrial areas but was similar to Borrow Pit Lake in that it was located near agricultural land. Two sampling locations, RA-1-S1 and RA-1-S2, were selected in Reference Area 1.

The selected location for Reference Area 2 was two bodies of water in Monroe County, Illinois, at a location approximately 20 miles south of Dead Creek. Each water body contained one sampling station. RA-2-S1 was in Long Slash Creek north of the culvert where Merrimac Road crosses the creek. This section was similar to Dead Creek Segments B through E in that it was shallow and muddy. It was similar to Dead Creek Segment F in that it traversed an agricultural area. RA-2-S2 was a flooded borrow pit north of Fountain Creek and similar in depth, hydrology, and surrounding land use to the Borrow Pit Lake.



### 3.4.1.2 Surface Water Sampling and Testing

Surface-water samples were collected at an approximate depth of 60 percent of the creek water column (measured from the top of the water column). All surface-water samples were collected prior to implementation of the Time-Critical Sediment Removal Action (Section 2.3.2). Sufficient water was not available to sample three of the stations in Creek Segment C and two of the stations in Creek Segment E. A total of 20 surface-water samples were collected. Each sample was analyzed for VOCs, SVOCs, pesticides, herbicides, PCBs, dioxin and metals. In addition, the samples were analyzed for fluoride, hardness, ortho-phosphate, total dissolved solids (TDS), total phosphorous, and total suspended solids (TSS). For discussion of the field procedures that were followed during sample collection and documentation related to the surface-water sampling, refer to Section 3.21 (Volume 5) of the FSR.

The surface water sampling and testing results for Dead Creek were likely to have been influenced by the presence of contaminated sediments in Dead Creek that were later removed during the Time-Critical Sediment Removal Action (Section 2.3.2). As a result, these surface water samples are not representative of current conditions.

### 3.4.1.3 Surface Water Investigation Results

Surface-water sampling analytical results are summarized in Table 3-41 (Creek Segment B), Table 3-42 (Creek Segment D), Table 3-43 (Creek Segment E), Table 3-44 (Creek Segment F), Table 3-45 (Site M), Table 3-46 (Borrow Pit Lake), Table 3-47 (Prairie du Pont Creek), and Table 3-48 (Reference Areas).

The primary VOC found in the Dead Creek surface-water samples was acetone, which was reported as estimated values and is a typical laboratory artifact. Two VOCs were detected in Creek Segment B: acetone (FOD 67%) with a maximum detected concentration of 18 ug/l and chlorobenzene (FOD 33%) with a maximum detected concentration of 2.8 ug/l. Acetone was also detected in Creek Segment D with a FOD of 100% and a maximum concentration of 17 ug/l. No VOCs were detected in Creek Segment E but benzene was detected in Creek Segment F with an FOD of 33% and a maximum concentration of 1.7 ug/l. Acetone was detected in the Borrow Pit Lake with a FOD of 100% and a maximum concentration of 18 ug/l.

Pentachlorophenol was the only SVOC detected in Creek Segment B with an FOD of 33% and a maximum detected concentration of 1.0 ug/l. No SVOCs were detected in Creek Segment D. Three SVOCs were detected in the one surface-water sample collected in Creek Segment E: fluoranthene (1.2 ug/l), phenanthrene (0.67 ug/l) and pyrene (8.7 ug/l). Fluoranthene and phenanthrene were also detected in Creek Segment F with FODs and maximum concentrations for both constituents of 33% and 0.7 ug/l. No SVOCs were detected in the Borrow Pit Lake.

Total pesticide concentrations in Dead Creek ranged from a high of 0.1218 µg/L in Creek Segment B to none detected in Creek Segment F and Prairie du Pont Creek. Thirteen pesticides were detected in both Creek Segment B and Creek Segment D with maximum concentrations ranging from 0.0025 to 0.04 ug/l.

in the former and 0.0023 to 0.0454 ug/l in the latter. Four related pesticides (alpha, beta, delta and gamma BHC) were detected in Creek Segment E at maximum concentrations of 0.0028 to 0.028 ug/l. No pesticides were detected in Creek Segment F but twelve pesticides were detected in the Borrow Pit Lake with maximum concentrations ranging from 0.00094 to 0.02 ug/l. Maximum detected total pesticide concentrations in the Borrow Pit Lake (0.037 ug/L) were less than the average concentrations found at the two reference areas (0.046 ug/L).

Herbicides were not detected in Creek Segments B, D, E and F nor were they detected in the Borrow Pit Lake.

PCBs were detected in one of the twenty surface-water samples at an estimated concentration of 0.055 ug/l (Creek Segment D). Maximum Dioxin TEQs in Dead Creek were 21.7 parts per quadrillion (ppq) in Creek Segment B, 17.7 ppq in Creek Segment D, 2.95 ppq in Creek Segment E and 9.16 ppq in Creek Segment F. Dioxin was present in the Borrow Pit Lake at a maximum TEQ concentration of 1.16 ppq. The maximum Dioxin TEQ value in the Reference Area surface water was 27.0 ppq (Reference Area 2).

Maximum detected concentrations of lead (20 ug/l in the Borrow Pit Lake) and nickel (22 ug/l in Creek Segment D), which are two of the four Sauget Area 1 target metals, were lower in Dead Creek than the maximum detected concentrations for lead (32 ug/l) and nickel (24.5 ug/l) in the Reference Area surface-water samples. The maximum detected concentration of zinc, 130 ug/l in Creek Segment B, was the same as the maximum detected concentration in the Reference Area surface-water samples. Copper was the only target metal with a maximum detected concentration in Dead Creek (130 ug/l in Creek Segment B) higher than the maximum detected Reference Area concentration (18.5 ug/L) but the maximum detected copper concentration in the Creek Segment F was 7.4 ug/l and no copper was detected in Prairie du Pont Creek.

With completion of sediment removal in February 2002, downstream migration of sediments from Creek Segments B, C, D, E and F during storm conditions is no longer a significant migration pathway.

### **3.4.2 Sediment Investigation**

As described in Section 2.3.2, all sediments were removed from Creek Segments B, C, D, E and F and Site M in 2000/2001 and transferred to the Judith Lane containment cell as part of the Time-Critical Sediment Removal Action. The sediments described below are no longer in Dead Creek.

#### **3.4.2.1 Sediment Investigation Sampling**

Vertically-integrated sediment core samples were collected in Creek Segments B, C, D, E and F; Site M; the Borrow Pit Lake, and Prairie du Pont Creek in order to evaluate the downstream extent of industry-specific and broad-scan constituents, and to provide information for use in the HHRA and the ERA. Sediment samples were analyzed for two separate sets of parameters – industry-specific constituents (Total PCBs, TPH, copper and zinc) and broad-scan constituents (Target Compound List/Target Analyte List). Industry-specific sediment sampling and analytical results are not discussed here because all of these constituents, with the exception of TPH, were included in the broad-scan sediment sample

analyses. Analytical results for the industry-specific sediment samples are included in the Sauget Area 1 EE/CA and RI/FS Support Sampling Plan Data Report (O'Brien and Gere, 2001).

Broad-scan sediment samples were collected at three sampling stations in Creek Segments B, C, D, E and F (three stations per creek segment) at the locations shown on Figure 3-9. In addition, sediment samples were collected at three sampling stations in the Borrow Pit Lake, two sampling stations in Reference Area 1 and two sampling stations in Reference Area 2 (Figure 3-9). Reference Areas were water bodies physically comparable to those in the Dead Creek watershed in order to provide a basis for comparison with Dead Creek and Borrow Pit Lake and were located away from the direct influence of industrial discharges, including major highways. Samples were collected using an Ekman grab sampler or by using stainless-steel trowels and spoons. For more information concerning these sampling procedures, refer to the Ecological Risk Assessment (Menzie-Cura, 2001). The nomenclature used to identify these samples was similar to the following: "SED-CSB-S1-0.2FT". This nomenclature was identical to the labels used for the industry-specific constituents, except that the symbol "SED" (which stands for sediment) was used in place of "FASSED".

Site M was characterized by collecting one surface-sediment sample and four vertically integrated sediment samples. Broad-scan analyses were performed on the surface sample, which was labeled "SED-M-S1-0.2FT". The nomenclature "SED" identified a sediment sample; "M" designated Site M, "S1" designated the sample number, and "0.2 FT" identified the sample depth. Four composite sediment samples were collected from Site M as well. Samples were collected from depths of 0 to 1.5 feet at two locations, and 0 to 2 feet at two locations. Composite sediment samples from Site M were labeled similar to the following: WASTE-M-B1-0-1.5FT where WASTE identified the sample as being handled similar to composite waste samples from the other fill areas, M identified the sample as coming from Site M, B1 was the boring location number, and 0-1.5FT identified the depth interval for the composite sample.

Prairie du Pont Creek is located at the southern (downstream) end of Creek Segment F and routes all of the water from Dead Creek to the Mississippi River. To evaluate the impact of the Dead Creek discharge on sediment quality in Prairie du Pont Creek, one broad-scan sediment sample was collected upstream and one broad-scan sediment sample was collected downstream of the confluence of Dead Creek and Prairie du Pont Creek. These two broad-scan sediment samples were numbered in the following manner: BSSSED-PDC-S-0-30IN and BSSSED-PDC-N-O-20IN. The nomenclature "BSSSED" identified the sampling parameters as broad scan sediments; the "PDC" identified that the sample was collected at Prairie du Pont Creek; the "N" and "S" identified that the sample was collected north and south of the Prairie du Pont Creek and Dead Creek intersection, respectively; and the "0-20IN" identified the sampling interval.

Sediment samples were collected from Prairie du Pont Creek via the procedures described in the FSR, except an additional VOC sample was collected using EnCore® samplers per USEPA Method 5035. The upstream sample in Prairie du Pont Creek was collected at an appropriate distance from the confluence with Dead Creek so that possible previous effects of flooding and flow reversals would not affect the collection of the background sample. As reported in the 1996 Hazard Ranking System (HRS) package prepared by PRC Environmental Management, Inc. for USEPA Region V, a background sampling station was located 200 feet north (upstream) of the confluence of Dead Creek and Prairie du Pont Creek. The sediment background sample was collected at this approximate location.

With the exception of the vertically integrated sediment samples from Site M, broad-scan sediment samples were analyzed for VOCs, SVOCs, pesticides, herbicides, PCBs, dioxin and metals. TCLP extracts of the vertically-integrated samples from Site M were analyzed for VOCs, SVOCs, pesticides, herbicides, PCBs, dioxin and metals, similar to the subsoil and waste samples collected in from Sites G, H, I, L and N.

### **3.4.2.2 Sediment Investigation Results**

Broad-scan sediment analytical results are summarized in Tables 3-49 to 3-53 (Creek Segments B, C, D, E and F), Table 3-54 (Borrow Pit Lake), Table 3-55 (Prairie du Pont Creek) and Table 3-56 (Reference Areas). Analytical results for Site M sediment and bottom soil samples are presented in Tables 3-57 and 3-58, respectively.

After a review of historical data (Ecology and Environment, 1988 and 1998), Total SVOCs, PCBs, Dioxin TEQ and copper were selected as representative indicator compounds for evaluation of downstream migration of site-related constituents in Dead Creek sediments.

## **3.5 Soil Investigation**

### **3.5.1 Background Soil Investigation**

Three shallow soil samples and three subsurface soil samples were collected to establish background soil conditions in Sauget Area 1. Background soil samples were collected near the locations of the wells that were sampled for upgradient groundwater background data, specifically EE-04, EE-20 and EEG-108 which are located upgradient of sites G, I and L, respectively (Figure 3-10). Background soil samples were collected from depths of 0 to 0.5 feet (surface soil samples) and three to six feet below ground surface (subsurface soil samples) at the three locations. The samples were numbered with nomenclature that defined the background well and sampling depth such as: BS-EE-20-0-0.5FT. The "BS" stands for background sample, "EE-20" identifies the background monitoring well that the sample was collected near, and the remainder of the label identifies the sample depth. A total of six total samples were collected and analyzed for VOCs, SVOCs, pesticides, herbicides, PCBs, dioxin and metals. In addition, surface soil samples were analyzed for bulk density, moisture content, pH and specific gravity. For more information pertaining to the procedures that were followed during sample collection, refer to Section 3.19 of the FSR (Volume 4).

Tables 3-59 and 3-60 summarize, respectively, the results of the background surface and subsurface soil sample analyses. More constituents were detected in surface soils than subsurface soils, and at higher concentrations, so only surface soil results are discussed in this section. Maximum detected concentrations of VOCs, SVOCs, pesticides, herbicides, PCBs, dioxin and target metals are given below:

Maximum Detected Constituent Concentrations in Sauget Area 1 Background Surface Soils

Constituent		Maximum Detected Concentration (mg/kg)
VOCs	2-Hexanone	0.018
	Dichloromethane	0.012
SVOCs	Anthracene	0.008
	Benzo(a)anthracene	0.170
	Benzo(a)pyrene	0.150
	Benzo(b)fluoranthene	0.110
	Benzo(g,h,i)perylene	0.082
	Benzo(k)fluoranthene	0.140
	Bis(2-ethylhexyl)phthalate	0.420
	Carbazole	0.032
	Chrysene	0.020
	Diethylphthalate	0.110
	Di-n-butylphthalate	0.240
	Fluoranthene	0.440
	Pentachlorophenol	0.045
	Phenanthrene	0.290
	Pyrene	0.360
Pesticides	4,4'-DDE	0.020
	4,4'-DDT	0.017
Herbicides	MCPA	13
	MCPP	6.55
	2,4,5-TP (Silvex)	0.013
PCBs	Total PCBs	1.71
Dioxin	Dioxin TEQ (Human Health)	0.000203
Target Metals	Copper	190
	Lead	180
	Nickel	28
	Zinc	820

### 3.5.2 Floodplain Soil Investigation

While localized flooding (ponded water) occurs in Sauget Area 1 during periods of significant precipitation, it is the result of the: 1) lack of relief, poor drainage and absence of storm drains in the floodplain area, and 2) use of Dead Creek and the Borrow Pit Lake for stormwater retention by the Metro East Sanitary District (MESD). Stormwater periodically backs up in Dead Creek since MESD does not operate the lift station at Prairie du Pont Creek until the stormwater storage capacity of Dead Creek and the Borrow Pit Lake is fully utilized. The pumps come on at a pre-set level so that the stormwater does not cause overbank flooding. Overbank flooding from Dead Creek is very unlikely because the discharge from Dead Creek is controlled by a lift station at Prairie du Pont Creek. Based on these considerations, significant scouring of sediments with subsequent deposition in the floodplain was not expected.

In order to confirm this premise and further explore this potential migration pathway, a series of floodplain surface (0.0 to 0.5 ft bgs) and subsurface (3.0 to 6.0 ft bgs) soil samples were collected along transects adjacent to Dead Creek in both developed and undeveloped areas of its floodplain. Sampling methods and results are discussed below.

### 3.5.2.1 Undeveloped Area Floodplain Soil Investigation

Surface and subsurface soil samples were collected at evenly spaced 200-ft. intervals on seven transects located in undeveloped areas adjacent to Dead Creek (Figure 3-10) to evaluate the extent of migration via the surface water (overbank flow) and air (wind-blown dust) pathways. Four transects were located on the west bank of Dead Creek (UAS - T1, T3, T5 and T7) and three were on the east bank (UAS - T2, T4 and T6). Soil samples were collected at a total of 45 sampling stations: seven stations on Transect T1, six stations on Transect T2, seven stations on Transect T3, seven stations on Transect T4, six stations on Transect T5, five stations on Transect T6 and seven stations on Transect T7.

Surface soil samples were collected from 0 to 0.5 feet below ground surface at each of the 45 sampling stations and subsurface soil samples were collected from three to six feet below ground surface. Each sampling station was labeled with a designation defining transect number, sample number, and sample depth. An example of this nomenclature is the following: "UAS-T1-S1-0-0.5FT". "UAS" identified that the sample matrix was soil and was collected from an undeveloped area. "T1" identified the transect number, "S1" identified the sample number, and "0-0.5FT" was the sampling interval. Note that the lower sample numbers correspond to samples closer to Dead Creek. For example, sample number 1 (or S1) is located near the edge of Dead Creek in all transects, S2 is approximately 200 feet from Dead Creek, and each consecutive sample number represents a sampling station that is 200 feet farther along the transect. S7 is located approximately 1,200 feet from Dead Creek. For more information pertaining to the procedures that were followed during sample collection, refer to Section 3.17 of the FSR (Volume 4).

Surface and subsurface soil samples were analyzed for VOCs, SVOCs, pesticides, herbicides, PCBs and metals. Moisture content, bulk density, specific gravity and pH were also determined for each sample. Twenty percent of the surface soil samples were analyzed for dioxins to provide data for the HHRA and the ERA. The total number of soil samples collected for dioxin analysis was 18 (nine surface soil samples, and nine subsurface soil samples).

### 3.5.2.2 Developed Area Floodplain Soil Investigation

Surface and subsurface soil samples were collected at 20 locations adjacent to the seven undeveloped area soil sampling transects discussed above (Figure 3-10). Three soil samples (both surface and subsurface) were collected at residences adjacent to Transects 1 through 6, and two soil samples (both surface and subsurface) were collected adjacent to Transect 7. Visual observation (discoloration) and field PID readings were recorded for the samples. Surface soil samples were collected from 0 to 0.5 feet below ground surface at each of the 20 sampling stations and subsurface soil samples were collected from three to six feet below ground surface. Each sampling station was labeled with similar designations as was used for the undeveloped areas (Section 3.4.2.1), except DAS (meaning developed area sample) replaced UAS. For more information pertaining to the procedures that were followed during sample collection, refer to Section 3.18 of the FSR (Volume 4).

Developed area floodplain surface and subsurface soil samples were analyzed for VOCs, SVOCs, pesticides, herbicides, PCBs, dioxin and metals. Moisture content, bulk density, specific gravity and pH

were also determined for each sample. Twenty percent of the subsurface soil samples (a total of four samples) were also analyzed for dioxin to provide data for the HHRA and ERA.

### 3.5.2.3 Floodplain Soil Investigation Results

Summary statistics for detected constituent concentrations in undeveloped area floodplain surface and subsurface soils are presented in Tables 3-61 to 74 while those for developed area floodplain surface and subsurface soils are given in Tables 3-75 to 3-88. As discussed in Section 3.4.2.2, a review of historical data (Ecology and Environment, 1988 and 1998) indicated that Total SVOCs, Total PCBs, Dioxin TEQ and copper were representative indicator compounds for evaluation of downstream migration of site-related constituents in Dead Creek sediments. Maximum concentrations of Total SVOCs, PCBs, Dioxin TEQ and copper in floodplain soil samples from Creek Segments B, C, D and E are discussed below.

**Creek Segment B** - Maximum detected concentrations of Total SVOCs, Total PCBs, Dioxin TEQ and copper in Creek Segment B floodplain soils are presented below:

CREEK SEGMENT B FLOODPLAIN SOIL - MAXIMUM DETECTED INDICATOR COMPOUND CONCENTRATIONS				
Constituent	Total SVOCs (mg/kg)	Total PCBs (mg/kg)	Dioxin TEQ (mg/kg)	Copper (mg/kg)
CS-B Sediments	22.05	226	0.0134	11,000
Background Soil	1.374	0.600	0.000062	190
Floodplain Surface Soil				
UAS-T1 (West)	0.037	0.244	0.00000618	230
UAS-T2 (East)	0.823	0.164	0.0000102	140
DAS-T1 (East)	0.160	0.072	0.0000156	97.5
DAS-T2 (East)	0.719	0.041	0.000012	110
Floodplain Subsurface Soil				
UAS-T1 (West)	0.200	0.0201	ND	24
UAS-T2 (East)	0.160	ND	0.0000501	16
DAS-T1 (East)	ND	ND	0.000000162	13
DAS-T2 (East)	ND	ND	0.000000128	10

- Notes:
- 1) ND = Not Detected
  - 2) UAS-T1 = Undeveloped floodplain soil sampling transect number
  - 3) DAS-T1 = Developed floodplain soil sampling transect number
  - 4) Background concentrations are maximum concentrations
  - 5) West = Sampling transect on west bank of Dead Creek
  - 6) East = Sampling transect on east bank of Dead Creek

Maximum detected Total SVOC concentrations were all below background concentrations in developed and undeveloped floodplain soils in Creek Segment B. Surface soil Total SVOC concentrations were one to two orders of magnitude lower than the concentrations measured in adjacent Creek Segment B sediments. Total SVOC concentrations were often higher with increasing distance from the creek (Figure 3-11), further indicating no relationship to the adjacent sediments. Subsurface soil Total SVOC concentrations were generally lower than corresponding surface soil values.

Maximum detected Total PCB concentrations in developed and undeveloped floodplain surface soils were lower than background concentrations, and did not display noticeable trends relative to distance from the creek (Figure 3-12). PCBs were detected in only two subsurface samples; both at sampling transect UAS-T1. Subsurface soil Total PCB concentrations were generally lower than corresponding surface soil values.

Maximum detected Dioxin TEQ concentrations were two to three orders of magnitude lower than concentrations measured in Creek Segment B, all below Sauget Area 1 background concentrations and did not display noticeable trends relative to distance from the creek (Figure 3-13).

Maximum detected copper concentrations in developed and undeveloped floodplain surface soils were two orders of magnitude lower than the average concentrations measured in Creek Segment B, but an order of magnitude higher than Sauget Area 1 background levels. No noticeable trends relative to distance from the creek were apparent (Figure 3-14).

**Creek Segment C** – Maximum detected concentrations of Total SVOCs, Total PCBs, Dioxin TEQ and copper in Creek Segment C floodplain soils are presented below:

CREEK SEGMENT C FLOODPLAIN SOIL - MAXIMUM DETECTED INDICATOR COMPOUND CONCENTRATIONS				
Constituent	Total SVOCs (mg/kg)	Total PCBs (mg/kg)	Dioxin TEQ (mg/kg)	Copper (mg/kg)
CS-C Sediments	13.43	4.6	0.00317	2,200
Background Soil	1.374	0.600	0.000062	190
Floodplain Surface Soil				
UAS-T3 (West)	9.69	0.116	0.00000327	79
UAS-T4 (East)	58.595	0.058	0.0000114	180
UAS-T5 (West)	1.775	0.173	0.00000441	84.5
DAS-T3 (West)	1.435	0.030	0.00000438	72
DAS-T4 (East)	2.121	0.0675	0.00000604	79
DAS-T5 (West)	7.369	0.035	0.0000243	75
Floodplain Subsurface Soil				
UAS-T3 (West)	0.173	0.0095	0.000000021	19
UAS-T4 (East)	125.394	0.0539	0.000000018	30
UAS-T5 (West)	0.585	ND	0.000000105	16
DAS-T3 (West)	0.377	ND	NA	12
DAS-T4 (East)	0.1325	0.01	NS	12.5
DAS-T5 (West)	0.126	ND	0.00000003	12

- Notes:
- 1) ND = Not Detected
  - 2) NS = Not Sampled
  - 3) UAS-T1 = Undeveloped floodplain soil sampling transect number
  - 4) DAS-T1 = Developed floodplain soil sampling transect number
  - 5) Background concentrations are maximum concentrations
  - 6) West = Sampling transect on west bank of Dead Creek
  - 7) East = Sampling transect on east bank of Dead Creek

Total SVOC concentrations in both surface and subsurface soils exceeded Creek Segment C sediment concentrations and background soil concentrations at undeveloped area sampling transect UAS-T4 located along the east side of the Dead Creek (Figure 3-11). The highest Total SVOC concentrations on this sampling transect were located within the boundary of Site N. Maximum detected Total SVOC concentrations at transects UAS-T3, DAS-T4 and DAS-T5 exceeded background soil concentrations for surface samples, but were less than the maximum concentration measured in Creek Segment C sediments. Except for transect UAS-T4, subsurface sample concentrations of Total SVOCs were one to two orders of magnitude less than the respective surface soil concentrations. No trends were observed with increasing distance from the creek.

The maximum detected Total PCB concentrations in developed and undeveloped floodplain surface soils were two to three orders of magnitude lower than the maximum concentrations measured in Creek



Segment C sediments and were also below the average background concentrations measured in Sauget Area 1. PCBs were detected in subsurface samples at three sampling transects (UAS-T3, UAS-T4 and DAS-T4). No trends were observed with increasing distance from the creek (Figure 3-12).

Maximum Dioxin TEQ concentrations were one to three orders of magnitude lower than maximum concentrations measured in Creek Segment C sediments, and below average background levels. No trends were observed with increasing distance from the creek (Figure 3-13).

The maximum detected copper concentrations in developed and undeveloped floodplain surface soils were two to three orders of magnitude lower than the maximum concentrations measured in Creek Segment C sediments. Subsurface soil maximum copper concentrations were comparable to Sauget Area 1 background levels. No trends were observed with increasing distance from the creek (Figure 3-14).

**Creek Segment D** - Maximum-detected concentrations of total SVOCs, PCBs, Dioxin TEQ and copper in Creek Segment D floodplain soils are presented below:

CREEK SEGMENT D FLOODPLAIN SOIL - MAXIMUM DETECTED INDICATOR COMPOUND CONCENTRATIONS				
Constituent	Total SVOCs (mg/kg)	Total PCBs (mg/kg)	Dioxin TEQ (mg/kg)	Copper (mg/kg)
CS-D Sediments	7.97	1.15	0.000717	740
Background Soil	1.374	0.600	0.000062	190
Floodplain Surface Soil				
DAS-T6 (East)	52.007	0.179	0.00000732	56
Floodplain Subsurface Soil				
DAS-T6 (East)	ND	ND	0.000000057	12

- Notes:
- 1) ND = Not Detected
  - 2) UAS-T1 = Undeveloped floodplain soil sampling transect number
  - 3) DAS-T1 = Developed floodplain soil sampling transect number
  - 4) Background concentrations are maximum concentrations
  - 5) West = Sampling transect on west bank of Dead Creek
  - 6) East = Sampling transect on east bank of Dead Creek

The maximum Total SVOC concentrations for developed area surface soils samples from transect DAS-T6 exceeded both Creek Segment D sediment and background soils concentrations. However, the highest concentration measured along this transect was found at sampling station DAS-T6-S3-3-6FT located slightly away from the creek along Jerome Lane (Figure 3-11). Total SVOC concentrations measured at proximate station UAS-T6-S1-0-0.5FT along Dead Creek were 0.160 mg/kg, indicating the DAS-T6 values may be attributed to another source. No SVOCs were found in subsurface soils analyzed at transect DAS-T6. Total SVOC concentrations increased from upstream to downstream in the Creek Segment D developed area soil samples.

Maximum detected Total PCB concentrations measured in surface soils at transect DAS-T6 were below background soils concentrations (Figure 3-12). No PCBs were detected in subsurface samples. Similarly, Dioxin TEQ concentrations measured at DAS-T6 were less than background soil concentrations, further indicating the absence of sediment migration to adjacent floodplain soils (Figure 3-13). Maximum detected copper concentrations in surface soils were more than two orders of magnitude lower than in Creek Segment D sediments, but above Sauget Area 1 background levels. No trends were

observed from upstream to downstream in the Creek Segment D developed area soil samples (Figure 3-14).

**Creek Segment E** - Maximum-detected concentrations of Total SVOCs, Total PCBs, Dioxin TEQ and copper in Creek Segment E floodplain soils are presented below:

CREEK SEGMENT E FLOODPLAIN SOIL - MAXIMUM DETECTED INDICATOR COMPOUND CONCENTRATIONS				
Constituent	Total SVOCs (mg/kg)	Total PCBs (mg/kg)	Dioxin TEQ (mg/kg)	Copper (mg/kg)
CS-E Sediments	6.29	1.04	0.000481	570
Background Soil	1.374	0.600	0.000062	190
Floodplain Surface Soil				
UAS-T6 (East)	1.609	0.385	0.0000159	31
UAS-T7 (West)	5.166	0.090	0.00000295	130
DAS-T7 (West)	27.023	0.010	0.00000628	33
Floodplain Subsurface Soil				
UAS-T6 (East)	14.138	0.0043	0.00000192	35
UAS-T7 (West)	8.135	0.0084	0.000000084	33
DAS-T7 (West)	0.140	ND	NS	62

- Notes:
- 1) ND = Not Detected
  - 2) NS = Not Sampled
  - 3) UAS-T1 = Undeveloped floodplain soil sampling transect number
  - 4) DAS-T1 = Developed floodplain soil sampling transect number
  - 5) Background concentrations are maximum concentrations
  - 6) West = Sampling transect on west bank of Dead Creek
  - 7) East = Sampling transect on east bank of Dead Creek

Maximum detected Total SVOC concentrations in surface soil samples were below Creek Segment E sediment concentrations with the exception of transect DAS-T7 (Figure 3-11). The highest detected Total SVOC concentration in surface soils on sampling transect DAS-T7 occurred at station DAS-T7-S2, which was located between Dead Creek and the adjacent Quail Run trailer park. Maximum detected subsurface soil Total SVOC concentrations were higher than surface soil sample maximum concentrations at UAS-T6 and UAS T-7 but lower than surface soil concentrations at DAS-T7. No trends were observed with increasing distance from the creek (Figure 3-11).

Maximum detected Total PCB and Dioxin TEQ concentrations for surface and subsurface soils in all transects in this section of the Creek were less than background concentrations, indicating that these constituents did not migrate from sediments to floodplain soils. Maximum detected copper concentrations for surface and subsurface soils were one order of magnitude lower than maximum sediment concentrations in Creek Segment E. No trends in Total PCB, Dioxin TEQ or copper concentrations were observed with increasing distance from the creek (Figures 3-12, 3-13 and 3-14).

#### 4.0 SUPPLEMENTAL REMEDIAL INVESTIGATION (2002 TO 2007)

Several supplemental investigations were performed during the period from 2002 through 2007 to address identified data gaps at Sauget Area 1. The supplemental investigations included exploratory trenching and sampling by a USEPA contractor, a DNAPL investigation, groundwater sampling to support a regional groundwater flow and contaminant transport modeling study, a vapor intrusion investigation, a subsurface investigation in a utility corridor along Queeny Avenue, and a soil-to-groundwater migration investigation for soil underlying Dead Creek. These supplemental investigations are summarized in this section.

##### 4.1 Site G, H, I, L, and N Supplemental Investigations

During 2002-2003, Tetra Tech EM Inc. (Tetra Tech) was contracted by USEPA to perform site investigations at Sites H, I South, L, and N under the EPA's Superfund Technical Assessment and Response Team (START) program (Tetra Tech, 2003a, 2003b, and 2003c). Trenching locations were selected by Tetra Tech and USEPA based on review of historical aerial photographs. The investigations were not intended to delineate the extent of the fill areas but to investigate the presence and nature of the waste, the presence and extent of buried drums, and the chemical constituents in the fill materials and in shallow groundwater. The investigations were conducted as described below:

- Exploratory trenches were advanced using a trackhoe machine that removed soil in 1 to 2 foot thick lifts. All excavated materials were stockpiled on plastic sheeting.
- Excavated materials were visually examined and screened for organic vapors using a PID and/or FID. Samples of waste materials and/or fill soil were collected for laboratory analysis. The samples were submitted to for laboratory analysis of VOCs, SVOCs, pesticides, metals, and PCBs. A subset of the waste and soil samples was analyzed for dioxins/furans.
- Excavated materials were backfilled into the trenches and the trench locations were restored.
- Groundwater samples were collected using direct-push drilling equipment at Sites I South and L. A rod with a retractable screen was advanced to a depth of approximately 22 feet, and the screen was exposed from 18 to 22 feet to allow water to enter the screen. After water levels were measured, a peristaltic pump was used to purge and to collect groundwater samples. After sampling, the rod and screen were withdrawn from the borehole, and the borehole was plugged.
- Six temporary wells were installed at Site N to depths ranging from 11 to 18 feet below grade using direct-push drilling equipment. The wells were constructed of 1-inch diameter PVC with 5 ft or 10 ft of screen. Water levels were measured and the temporary wells were purged and sampled using a peristaltic pump. The samples were submitted to for laboratory analysis of VOCs, SVOCs, pesticides, metals, and PCBs. A subset of the groundwater samples was analyzed for dioxins/furans.
- An elevation survey was performed at Site N to determine the top of casing elevations of the temporary wells relative to an on-site datum. Water levels were measured one week after

installation of the temporary wells to determine groundwater flow direction at Site N, and the temporary wells were then plugged.

The work performed by Tetra Tech in 2002-2003 did not include investigations at Site G. However, as discussed below, Golder Associates collected samples of waste materials encountered on the surface of Site G at two discrete locations in June 2004 (Golder, 2004).

Figure 4-1 shows the trenches and groundwater sampling locations at Sites H, I South, and L, and the approximate location of the waste samples collected at Site G. Figure 4-2 shows the locations of trenches and temporary wells at Site N. The following sections briefly discuss the observations at each site.

#### **4.1.1 Site G**

Waste materials were observed at Site G in June 2004 at two discrete locations, designated L-1 and L-2 (Golder, 2004). These locations were along lines that had been cleared of vegetation to allow placement of geophone leads for a seismic survey, which was performed during the DNAPL characterization and remediation study. The waste at locations L-1 and L-2 appeared to be similar, consisting of a black material with a metallic luster and having the consistency of cold tar. The immediately surrounding soil was stained a dark yellowish brown. In addition, at L-2 there was a small dark yellow solid mass that appeared to have a crystalline structure. There was no discernable odor at either location, and a PID recorded no readings above background (Golder, 2004).

Golder collected a sample of the black tar-like substance, a sample of the yellow crystalline material, and a sample of the dark yellowish brown soil. As a result of the sampling, all of the visible waste materials (both the black tarry substance and the yellow crystalline material) were removed from the site at the two locations where they were observed. Temporary covers were constructed at areas L-1 and L-2. The covers consisted of low-density polyethylene (LDPE) over the visibly affected area of the ground surface, covered by 12 inches of clean soil imported from an off-site source. The soil was compacted with construction equipment and graded to drain.

The waste samples were submitted for laboratory analysis of VOCs, SVOCs, PCBs, pesticides, herbicides, and metals. Field procedures, site photographs, and analytical results were documented in a letter report (Golder, 2004). Laboratory results indicated that all three waste samples had elevated concentrations of 2-nitroaniline and 4-nitroaniline. Other constituents detected at elevated concentrations in one or more samples included 4-chloroaniline; 1,4-dichlorobenzene; nitrobenzene; PCBs; and certain pesticides and herbicides.

#### **4.1.2 Site H**

Tetra Tech excavated two trenches at Site H in July 2002. The waste materials found in the trenches included filter paper, crystalline material, catalyst beads, sand-like material, and various soils. No drums were observed in the two trenches at Site H. An oily sludge material removed from trench T1 had a maximum PID reading of 12.7 ppm. A total of four waste samples and three soil samples were submitted for laboratory analysis of VOCs, SVOCs, pesticides, metals, and PCBs. Analytical results were presented

on Tables 2, 3, and 4 in the site investigation report (Tetra Tech, 2003a). During site restoration the following day it was noted that both trenches had a noticeable odor, so additional clean soil was delivered to cover the trenches. No groundwater samples were collected during the investigation at Site H.

#### **4.1.3 Site I South**

Tetra Tech excavated four trenches in July 2002 in Site I South at the truck parking area (Tetra Tech, 2003a). In October 2003, Tetra Tech excavated three trenches in a grassy area to the west of the Sauget Village Hall and collected one groundwater sample from that area (Tetra Tech, 2003c).

Fill materials observed in the trenches at the truck parking area included used brick and refractory brick interspersed with expended coal, wood products, rubber hoses, scrap steel, and wire. A total of four drums were found in three of the trenches. Two of the drums were sampled, including one that was in poor condition and contained a non-volatile tar-like substance, and one that contained a cement-like substance. Waste samples were also collected from various substances encountered in the trenches, including filter cake material, crystalline material, filter cloth, sludge-like material, granular beads, a purple substance, yellow crystalline rock, a shiny pumice-like substance, and a black oily material that had a petroleum odor.

At the Sauget Village Hall property, fill materials encountered in the main trench, Site I-T1, included construction debris consisting of soil, concrete, brick, wood, metal, glass, and rubber hoses. No drums were found in this trench. Waste samples were collected from various substances, including a yellow and white sludge material with an FID reading of 130 ppm, a black material with FID readings of 320 to 416 ppm, a black material with oily catalyst beads, and a black soil with broken battery casings and plastic. The northern portion of the main trench was extended about 8 feet to the east to determine if construction debris was present underneath the Village Hall parking lot, and no construction debris was encountered. This suggests that the edge of the Village Hall parking lot is the approximate eastern boundary of waste at Site I South (Figure 4-1).

One of the two smaller trenches, Site I-T2, contained a few pieces of asphalt and concrete, and the other small trench, Site I-T3, had no construction debris or waste. No samples were collected from the two smaller trenches because PID and FID readings indicated no evidence of contamination. The absence of construction debris or waste at trench Site I-T3 provides further evidence to suggest that the edge of the Village Hall parking lot is the approximate eastern boundary of waste at Site I South.

A total of thirteen waste samples from trenches in the truck parking area and four waste samples from the main trench in the grassy area west of the Village Hall property were submitted for laboratory analysis of VOCs, SVOCs, pesticides, metals, and PCBs. One groundwater sample was collected from the Village Hall property for laboratory analysis of VOCs and metals. Analytical results are presented in two separate site investigation reports (Tetra Tech, 2003a and 2003c).

#### **4.1.4 Site L**

In March 2003, Tetra Tech excavated five trenches at Site L and used direct-push drilling equipment to collect ten groundwater samples (Tetra Tech, 2003b). Waste materials in trench L-T1 consisted primarily

of soil, concrete, and industrial debris such as pipes and wires. Four drums were encountered in the western section of trench L-T1 at a depth of 8 to 12 ft bgs. The first drum contained a black oily liquid and a yellowish to cream-colored solid the consistency of paint. The second drum was badly crushed and appeared to contain paint solids. A sample of a black and tan sandy material collected from 14 ft bgs had an FID headspace reading of 1200 ppm. Black stained soil was encountered in the middle and eastern portions of trench L-T1, and soil samples from these locations had headspace readings of 290 ppm and 37 ppm, respectively. A reddish-brown and black soil material found in a deteriorated paper bag yielded an FID reading of 290 ppm.

Waste materials in trenches L-T2, L-T3, L-T4, and L-T5 consisted primarily of soil and construction debris such as brick, pipes, concrete, and wood. FID readings for soil samples from trenches L-T2, L-T3, and L-T4 ranged from 10 to 118 ppm. FID readings for the two soil samples from trench L-T5 were 750 ppm and 1500 ppm.

A total of two waste samples collected from drums, fourteen soil samples, and ten groundwater samples were submitted for laboratory analysis. Analytical results are presented on Tables A-1 through A-10 in the site investigation report for Site L (Tetra Tech, 2003b).

#### **4.1.5 Site N**

In October 2003, Tetra Tech excavated six trenches at Site N and installed and sampled six temporary wells. Site N is located on property formerly owned by the H. Hall Construction Company and was primarily used for disposal of construction debris. Tetra Tech described the waste observed in the trenches as construction debris consisting of soil, brick, concrete, metal, tires, and wood. Creosote odors were sometimes noted during trenching. A total of 21 drums were uncovered at Site N, including 19 empty crushed drums, one crushed drum with a waste oil odor (FID reading of 72 ppm), and one crushed drum with a white paint-like sludge (FID reading of 600 ppm). The white paint-like sludge could have been painting waste, which would be consistent with the former use of Site N for disposal of construction debris. Samples of black soil found in discrete areas of trenches N-T1 and N-T2 had FID readings of 300 ppm and 710 ppm, respectively. All other soil samples had FID readings ranging from 0 to 97 ppm.

A total of six soil samples and six groundwater samples from Site N were submitted for laboratory analysis. Analytical results are presented on Tables A-1 through A-10 in the site investigation report for Sites I and N (Tetra Tech, 2003c). Based on results of the water level survey, Tetra Tech determined that shallow groundwater flow at Site N is toward the northwest.

## **4.2 DNAPL Investigation**

### **4.2.1 DNAPL Characterization and Remediation Study**

In a letter dated January 9, 2003, USEPA required the performance of a DNAPL characterization and remediation study at Sauget Area 1. The DNAPL characterization and remediation study was conducted from May to December 2004, in accordance with a Work Plan dated April 1, 2004 (GSI, 2004). To address USEPA comments, additional work was conducted from September to December 2005, in accordance with a supplemental work plan dated August 2, 2005.

DNAPL characterization activities included the following: i) NAPL surveys and recovery tests; ii) a 3-D seismic reflection survey to map the topography of the bedrock surface; iii) soil sampling and piezometer installation at 19 locations; iv) bench-scale DNAPL treatability tests; and v) downhole geophysical logging at bedrock well BR-I.

#### **4.2.1.1 NAPL Surveys and Recovery Tests**

**NAPL Surveys in 2004-2005** - A NAPL survey was performed in May 2004 at 57 wells and piezometers in existence prior to the start of the DNAPL characterization study. NAPL surveys were performed in October 2004 and September 2005 at newly installed DNAPL piezometers A1-1 through A-18 and a subset of the previously existing wells. Additional DNAPL thickness measurements were collected during October to December 2005 at A1-19 and BR-I. NAPL survey procedures included the use of an interface probe and clear bailer to check for LNAPL on top of the water table and the use of an interface probe, weighted cotton string, and clear bailer to check for DNAPL at the bottom of each well.

An accumulation of LNAPL was found at well EE-11 at Site G, and an accumulation of pooled DNAPL was found at BR-I and A1-19, which are located about 10 feet apart at Site I South (see Figure 4-3). Some evidence of DNAPL was observed in BR-G. Droplets of DNAPL were observed at A1-08 during the October 2004 survey but not during the September 2005 survey. There was no evidence of LNAPL or DNAPL in any of the other wells or piezometers surveyed in 2004-2005.

**NAPL Recovery Tests in 2004-2005** - Two LNAPL recovery tests were performed at well EE-11 at Site G. The first LNAPL recovery test was performed in May 2004 using a peristaltic pump and recovered an accumulation of LNAPL that was sampled for field testing and laboratory analysis. The second test was performed in October 2004 using a clear bailer, and this test produced only small globs of LNAPL.

DNAPL recovery tests were performed at wells BR-G and BR-I using Waterra pumps. The recovery tests were conducted using alternating periods of pumping and resting. Each NAPL recovery test was terminated when at least one of the following conditions was met: i) the test was performed for at least 8 hours; ii) the test recovered a total of at least 100 gallons of fluids; or iii) no measurable NAPL was recovered during at least two consecutive pumping and rest cycles following the initial pumping period. Some evidence of DNAPL was noted at BR-G during well surveys, but no DNAPL was recovered during three separate recovery tests at BR-G.

DNAPL was recovered from BR-I, and a DNAPL sample from BR-I was retained for field testing and laboratory analysis. Recovery tests confirmed that BR-I is a low-yield well. After fluids stored in the 4-inch diameter PVC casing were pumped out, the yield was approximately 0.05 gpm of total fluids with drawdown of approximately 100 ft below static water level. After each recovery test, it took several days for the water level in BR-I to return to static conditions.

LNAPL from EE-11 at Site G and DNAPL from BR-I at Site I South were evaluated in the field for NAPL density, viscosity, temperature, and wettability. Containers of NAPL and water from these two wells were submitted for laboratory analysis of fluid properties including dynamic viscosity, fluid density, surface tension, and interfacial tension. Samples of the LNAPL and DNAPL were submitted for distillation testing

and for laboratory analysis of VOCs, SVOCs, pesticides, herbicides, PCBs, dioxin, and metals. Results of the laboratory analyses for the LNAPL and DNAPL samples are summarized in Appendix C of the DNAPL Characterization and Remediation Report (GSI, 2006c).

**Key Findings from NAPL Surveys and Recovery Tests** - As shown on Figure 4.3, results of the NAPL surveys and recovery tests performed in 2004 and 2005 indicate the following: i) further recovery of LNAPL at EE-11 by pumping does not appear feasible; ii) DNAPL is not present at A1-08; iii) some DNAPL may be present in BR-G, but recovery of DNAPL by pumping does not appear feasible; and iv) pooled DNAPL is present at BR-I and at A1-19.

#### **4.2.1.2 Seismic Reflection Survey**

A three-dimensional seismic reflection survey was conducted to map the topography of the bedrock surface and to identify topographic lows where pooled DNAPL could potentially accumulate. The seismic survey covered an L-shaped area approximately 44 acres in size encompassing Sites G, H, I South, I North, and L.

The seismic survey was conducted using a network of geophones and cables, a data acquisition and recording instrument, and an energy source. The energy source was a truck-mounted accelerated weight drop apparatus. Where truck access was not possible, a 20-lb sledgehammer was used as the energy source. To adequately image the bedrock surface, the lines of geophones were at 55 ft intervals. Downhole "check shot" surveys were conducted in BR-G, BR-H, and BR-I to generate seismic travel time to depth relationships. A geophysicist processed the seismic reflection data using a UNIX workstation and Promax 3D seismic processing software, and the result was an interpreted bedrock surface elevation map that was issued in August 2004. The USEPA and the PRP group used the map to help select and prioritize proposed locations for soil sampling and installation of bedrock piezometers.

Measured depths to bedrock and surveyed ground elevations for the first ten bedrock piezometers installed in September 2004 were provided to the geophysicist to improve the accuracy of the velocity model that was used for conversion of seismic reflection time to depth. The revised bedrock surface elevation map was completed by the geophysicist in October 2004 and was used by USEPA and the PRP group to help select remaining locations for soil sampling and installation of bedrock piezometers. Overall, the predicted bedrock elevations from the 3-D seismic survey were found to be more reliable at Sites H and I than at Site G, due to noisy and badly scattered data at Site G.

#### **4.2.1.3 Soil Sampling and Piezometer Installation**

A total of 19 piezometers were installed during the DNAPL characterization and remediation study (see Figure 4.3). Bedrock piezometers were installed inside and outside the fill areas and at predicted topographic low spots in the bedrock surface. One piezometer, A1-17, was installed to verify that the LNAPL found at EE-11 did not extend beyond the limits of the Site G fill area. The number of piezometers for each fill area was based on the size of the fill area and the potential magnitude of DNAPL impact. Accordingly, more piezometers were installed at Site I, compared with Site L, because Site I has



a larger surface area and has more potential for DNAPL impacts. The following tasks were performed during soil sampling and piezometer installation.

- Soil borings were advanced using sonic drilling equipment. Each boring was continuously cored through the fill materials, the alluvial deposits, and five or more feet into bedrock, except for the shallow piezometer, A1-17, which stopped at a depth of 25 ft bgs.
- Each soil core was examined and screened for NAPL based on the following methods: i) visual inspection of the core surface, ii) inspection of flexible reactive liner material (i.e., NAPL FLUTE strips) placed along the core surface, iii) measurement of headspace vapor concentrations using a PID, and iv) use of vial test kits containing Sudan IV dye. Each core was examined to determine soil type and was digitally photographed.
- One soil sample from each 10-foot depth interval of core was retained for laboratory analysis of VOCs and SVOCs. Samples were selected based on results of field screening and examination for NAPL or other evidence of organic constituents. In addition, a total of three “clean” soil samples (i.e., with little or no evidence of NAPL) were retained from each boring for analysis of fraction organic carbon.
- Several undisturbed cores were collected from each boring using a split-spoon sampler and were immediately placed on dry ice. These frozen cores were submitted to PTS Laboratory for possible testing for one or more of the following: i) physical properties (i.e., porosity, bulk density, and grain size classification); ii) pore fluid saturations; and iii) DNAPL mobility using a modified centrifuge test procedure.
- Each soil boring was completed as a piezometer. The bedrock piezometers were screened both above and below the bedrock surface and constructed of 2-inch diameter stainless steel casing with 15 feet of screen. The shallow piezometer, A1-17, was installed to a depth of 25 feet bgs with 15 feet of screen. After installation, each piezometer was developed and checked for the possible presence of LNAPL and pooled DNAPL. NAPL survey results from 2004-2005 are shown on Figure 4-3.

Core examination and field screening results, sample analytical data, testing results from the undisturbed cores, and boring log/as-built diagrams are presented in the DNAPL Characterization and Remediation Report (GSI, 2006c).

Figures 4.4 and 4.5 show the horizontal and vertical distribution of total chlorobenzenes and total chloroethenes in the fill and aquifer matrix. Total chlorobenzenes is defined as the sum of the concentrations of the following constituents: chlorobenzene; 1,2-dichlorobenzene; 1,3-dichlorobenzene; 1,4-dichlorobenzene; and 1,2,4-trichlorobenzene. Total chloroethenes is defined as the sum of the concentrations of tetrachloroethene; trichloroethene; cis-1,2-dichloroethene; trans-1,2-dichloroethene; and vinyl chloride.

For total chlorobenzenes in the SHU (0-30 ft bgs), the borings with the highest concentrations (>100 mg/kg) included A1-6, A1-8, A1-19 at Site I South, A1-2 at Site H, and A1-13 and A1-14 at Site G. The

maximum concentration of total chlorobenzenes in the SHU was 25,300 mg/kg at A1-8 (22.5 to 25 ft bgs). For total chlorobenzenes in the MHU and DHU, the borings with the highest concentrations included A1-8, A1-9, and A1-19 at Site I South and A1-14 at Site G. The maximum concentration of total chlorobenzenes in the MHU and DHU was 1620 mg/kg at A1-14 (112.5 to 115 ft bgs).

Concentrations of total chloroethenes were in general significantly lower than the concentrations of total chlorobenzenes. For total chloroethenes in the SHU (0-30 ft bgs), the borings with the highest concentrations (>10 mg/kg) included A1-8 and A1-9 at Site I South and A1-13 and A1-14 at Site G. The maximum concentration of total chloroethenes in the SHU was 36 mg/kg at both A1-9 (25 to 27.5 ft bgs) and A1-14 (12.5 to 15 ft bgs). Total chloroethenes concentrations in the MHU and DHU were relatively low and frequently were below detection limits. The maximum concentration of total chloroethenes in the MHU and DHU was 1.2 mg/kg at A1-9 (42.5 to 45 ft bgs).

#### 4.2.1.4 DNAPL Treatability Tests

Three potential source depletion technologies were evaluated in Section 5.0 of the DNAPL Characterization and Remediation Report (GSI, 2006c). The technologies that were evaluated included surfactant-enhanced solubilization, thermal treatment, and chemical oxidation. Treatability tests were conducted as part of this evaluation, and a comprehensive dissolution test was conducted at the bench-scale to provide data on mass flux and time required to deplete the source. Results of these tests were presented in Appendix G of the DNAPL Characterization and Remediation Report (GSI, 2006c) and are discussed below.

**Surfactant Treatability Test** - Surfactant flushing (with or without cosolvent) has been developed as an aggressive remediation technology for DNAPL contamination in the subsurface (Yin and Allen, 1999). The feasibility of this technology is based on the interaction between the surfactant and the contaminants in relation to the media in which they are present, typically water.

A bench-scale test was conducted using the DNAPL sample from well BR-I to determine the applicability of two different types of surfactants for enhancing solubility. Surfactants (Tween 80 and Aerosol MA-80I) were added at levels above their critical micelle concentrations to solutions containing DNAPL of known composition that was recovered from well BR-I. No consistent enhancement in solubilization was noted for any of the compounds of interest. The results from this treatability test suggest that surfactant-enhanced solubilization is not an appropriate technology selection for Sauget Area 1. Because increases in concentration following surfactant addition were not observed, no estimates can be made of the mass of surfactant needed to remove the constituents present at the site. While it is possible that surfactant amendments may have a more measurable impact on solubilization *in situ*, there is little indication that the compound profile is amenable to surfactant flushing.

**Thermal Treatment Evaluation Using DNAPL Boiling Point Data** - Thermal treatment is a general term for a variety of approaches designed to destroy or mobilize constituent mass *in situ*. Most methods involve the injection of heat (often in the form of steam) to vaporize and strip volatile compounds. It is not practical to dewater or completely boil off all water within the saturated zone at Sauget Area 1. One thermal treatment approach that does not require dewatering of the saturated zone is a combination of

Dynamic Underground Stripping and Hydrous Pyrolysis Oxidation (DUS/HPO). The DUS/HPO process involves the continuous injection of steam and oxygen to heat the aquifer to the boiling point of water and mobilize a portion of the contamination through volatilization and stripping. Recovery of volatilized constituents requires a series of extraction wells. Hydraulic control is used to recover a portion of the overall mass, including mobilized free product and aqueous phase constituents.

Laboratory analysis of the DNAPL sample from BR-I indicated that the principal constituents by mass fraction were 1,2,4-trichlorobenzene (14%); hexachlorobenzene (1%); and 1,4-dichlorobenzene (0.8%). These chemicals have minimum boiling points of 416°F, 630°F, and 346°F, respectively. Distillation test results using DNAPL from BR-I indicate that only 5% of the DNAPL has a boiling point at or below 432°F. The remaining 83% of the sample volume recovered had a boiling point that fell within the relatively narrow range of 432 to 530°F. These laboratory results are documented in Appendix C of the DNAPL Characterization and Remediation Report (GSI, 2006c)

Based on results from the BR-I DNAPL sample, the DNAPL constituents within the fill materials and alluvial aquifer matrix at Sauget Area 1 have relatively high boiling points, which indicates that volatilization is not likely to be the predominant source removal mechanism during thermal treatment using the DUS/HPO technology. Instead the predominant mass removal mechanism would likely be pumping of free product, based on results from the Visalia site, a well-documented site located in Visalia, California, where DUS/HPO thermal treatment technology was applied (US DOE, 2000). Heating of the fill materials and aquifer matrix at Sauget Area 1 would reduce interfacial tension and viscosity of residual DNAPL, thereby increasing the potential for DNAPL to move through the fill and aquifer matrix and be removed by pumping from recovery wells.

**Chemical Oxidation Treatability Test** - Chemical oxidation acts to deplete source mass via a chemical reaction between a strong oxidant with a reduced constituent with the goal of directly converting the compound to CO<sub>2</sub>. Common chemicals used for this purpose include hydrogen peroxide (H<sub>2</sub>O<sub>2</sub>), chloride dioxide (ClO<sub>2</sub>), and potassium permanganate (KMnO<sub>4</sub>). Potassium permanganate has been used for removing drinking water pollutants for several decades, and it has been applied in field demonstrations for removing DNAPL at the Borden site (Schnarr et al., 1998) and at the Portsmouth Gaseous Diffusion Plant in Ohio (U.S. DOE). On this basis, potassium permanganate was the chemical oxidant that was selected for further evaluation at Sauget Area 1.

Compounds identified in the Sauget Area 1 DNAPL include trichlorobenzene, dichlorobenzene, and chlorobenzene. The amount of permanganate needed to completely oxidize these compounds was determined from reaction stoichiometries. On a mass basis, this corresponds to ratios of 7.0 mg of KMnO<sub>4</sub> required per mg of trichlorobenzene, 9.3 mg of KMnO<sub>4</sub> required per mg of dichlorobenzene, and 13.1 mg of KMnO<sub>4</sub> required per mg of chlorobenzene.

During a study at another site in the Sauget area (the Solutia Inc. W.G. Krummrich Plant), a DNAPL sample was collected for a bench-scale chemical oxidation treatability test using permanganate. However, the test was not successful in converting all VOCs to CO<sub>2</sub>. The tests yielded ratios ranging from 15.7 to 148.3 grams of permanganate needed per gram of VOC oxidized, in part because the oxidation reaction was kinetically limited and non-selective. Because the Krummrich DNAPL is generally

similar in composition to that recovered at Sauget Area 1 (chlorinated benzenes), it is not expected that chemical oxidation would be an effective source depletion technology at Sauget Area 1.

**Dissolution Tests** - Dissolution of contaminants into the aqueous phase was considered as a baseline condition for remediation of the DNAPL source area. Estimates of persistence of contamination and time scales required for cleanup can be generated, and this provides a comparison case for natural attenuation and pump-and-treat remediation strategies. Dissolution tests were conducted using soil collected during the drilling program at Sauget Area 1. Site soil was added to bench-scale columns to model flow-through conditions in an aquifer. Dissolution was quantified in terms of the mass of constituents recovered per pore volume pumped through the column, or the number of pore volumes required to reach clean-up goals. Soil from the following borings and depth intervals was used: A1-8 (22.5-25 ft); A1-8 (70-72.5 ft); and A1-14 (25-27.5 ft).

Over the course of 50 pore volumes, passive dissolution resulted in depletion of total contaminant mass, but only minimal changes in total COC concentration were observed, suggesting that dissolution rates reached steady-state within a short period following the initiation of pumping. After 50 pore volumes, the total COC concentrations had decreased but within a range of only 10 to 30%. The flat concentration profile over time is consistent with studies that indicate that concentration changes in soil matrices containing NAPL are dependent on mass removal, and that significant changes in concentration are generally preceded by large changes in source mass (Newell and Adamson, 2004; Sale and McWhorter, 2001). In the case of the three soil samples used to create these columns, the total mass of COC present initially can be estimated using previous analyses of the core, and this mass can be compared to the cumulative mass in the effluent over time. After pumping 50 pore volumes, this percent removal of COCs ranged from 0.38 to 35%.

Analysis of the rate of concentration change versus pore volumes indicated that at a minimum 740 pore volumes, and potentially 2800 would be required for natural dissolution to treat the DNAPL zone. This analysis ignored one dissolution test column with no measurable decrease in concentration after 50 pore volume flushes. Detailed information regarding the treatability tests is found in Appendix G of the DNAPL Characterization and Remediation Report (GSI, 2006c).

#### **4.2.1.5 Downhole Geophysical Logging at Well BR-I**

Downhole geophysical logging surveys were performed at bedrock well BR-I to obtain more information about the condition of the well and the origin of pooled DNAPL found in the well. The logging surveys were performed by Colog in October 2005 and utilized an optical televiewer, acoustic televiewer, three-arm caliper, video, and a probe that measured fluid temperature/conductivity. Colog's report was included in Appendix I of the DNAPL Characterization and Remediation Report (GSI, 2006c).

Logging results indicated that the 4-inch diameter PVC casing in BR-I extends to a depth of 124.75 ft bgs, followed by an open borehole in the bedrock to a total depth of 146.9 ft bgs. The bottom portion of the PVC casing could not be observed directly due to the presence of DNAPL starting at a depth of 114.5 ft bgs. Colog's interpretation of the acoustic televiewer and caliper logs indicated no evidence of damage to

the bottom of the PVC casing. However, pooled DNAPL was in contact with the lower portion of the PVC casing, which suggested potential for some degree of chemical degradation of the PVC casing.

Within the open-hole portion of the well, a total of 42 acoustic features were observed at depths between 125.2 ft and 144.4 ft bgs. Colog ranked the acoustic features on a scale from 1 to 5 based on a ranking system developed by the U.S. Geological Survey. Of the 42 acoustic features observed in the open borehole, 13 had the rank of 3 (i.e., distinct feature with open aperture). One acoustic feature had the rank of 4 (i.e., very distinct, wide, possible interconnected fracture), and this feature was also observed on the caliper log. Although bedrock fractures are apparently present at BR-I, the low well yield (~0.1 gpm) observed during DNAPL recovery tests at BR-I demonstrates that these fractures transmit very little flow.

#### **4.2.2 DNAPL Recovery Studies at Well BR-I**

##### **4.2.2.1 DNAPL Recovery at BR-I (November 2006 to March 2007)**

Following review of the DNAPL Characterization and Remediation Report, USEPA requested that a DNAPL recovery study be performed at BR-I. This study was conducted from November 2006 to March 2007 in accordance with a work plan submitted to USEPA in August 2006.

The first task was to install a 2-inch diameter stainless steel well assembly within the existing 4-inch diameter PVC casing and open borehole. An electric-powered piston pump was then installed for DNAPL recovery. The pump included a downhole piston assembly, a 1.25-inch diameter HDPE riser pipe, an electric drive motor / actuator mounted on top of the wellhead, and a motor control box.

During the DNAPL recovery study, DNAPL and water were pumped from BR-I into drums once a week for 15 weeks. A portable generator was used as the power source for operating the electric-powered piston pump. During each visit, pumping was terminated when the DNAPL accumulation in the well was removed and the flow rate of recovered fluids exhibited a noticeable decrease to <0.1 gpm, typically after about 30 to 40 minutes of pumping. Each visit included measurement of flow rates, volumes of total fluids recovered, and depths to water and DNAPL in BR-I and A1-19 before and after pumping. Observations of the appearance and estimated DNAPL fraction of the recovered fluids were noted during pumping. After completion of the 15-week study, depth to water and depth to DNAPL were measured in each drum of recovered fluids in order to calculate an accurate volume of recovered DNAPL during the study.

Based on volume calculations for fluids in the drums, the recovered volumes were as follows:

- Volume of total fluids (DNAPL and water) recovered in 15 weeks: 299 gallons
- Volume of DNAPL recovered in 15 weekly events: 49 gallons
- Average DNAPL recovery: 3.3 gallons / event

Procedures and results of the study are documented in Results of DNAPL Recovery Study at BR-I, Revision 1 (GSI, 2008a).

Figure 4-6 illustrates the conceptual model for the presence of pooled DNAPL at and near BR-I. BR-I is screened in unweathered bedrock, which is overlain by a zone of weathered bedrock and the alluvial aquifer. The lowermost portion of the alluvial aquifer and the weathered bedrock apparently comprise the primary reservoir for pooled DNAPL entering BR-I. While the possibility of some DNAPL in fractures in the unweathered bedrock cannot be ruled out, the contribution of DNAPL to BR-I from unweathered bedrock, if any, is relatively small (GSI, 2008a).

#### 4.2.2.2 DNAPL Recovery at BR-I (October 2008 to May 2012)

A DNAPL recovery program was initiated at BR-I in October 2008. From October 2008 through November 2009, DNAPL was recovered from BR-I once every other week except during a two-week period in June 2009, when a total of 7 DNAPL recovery events were performed. The DNAPL and water recovered from BR-I were stored in a 500-gallon dual-wall poly tank located adjacent to BR-I. The procedures and results of the DNAPL recovery activities from October 2008 through November 2009 were documented in a letter report (GSI, 2009), and the key findings were as follows:

- **DNAPL Recovery from Every-Other-Week Pumping:** Approximately 440 gallons of total fluids (including 80 gallons of DNAPL) accumulated in the 500-gallon tank after a total of 22 every-other-week pumping events, for an average recovery of 3.6 gallons of DNAPL per event.
- **DNAPL Recovery from More Frequent Pumping in June 2009:** Approximately 125 gallons of total fluids (including 20 gallons of DNAPL) accumulated in three drums after a total of 7 pumping events during a two-week period in June 2009, for an average recovery of 2.9 gallons of DNAPL per event.
- **Presence of Pooled DNAPL at Piezometer A1-19:** A pooled DNAPL thickness of approximately 4.9 feet was consistently detected in A1-19, which is located 15 ft from BR-I. Pumping at BR-I does not appear to have any effect on the pooled DNAPL thickness in A1-19.

Approximately 1687 gallons of total fluids were removed from BR-I during the period from December 2009 through May 31, 2012, including an estimated 229 gallons of DNAPL. During this period, DNAPL was recovered from BR-I every other week, except from late January 2012 through April 2012, due to problems with the electric-powered piston pump. A new piston pump was installed in BR-I on May 1, 2012, and every other week DNAPL recovery resumed at that time.

A cumulative volume of approximately 378 gallons of DNAPL was recovered from BR-I during the entire period of DNAPL recovery (i.e., from November 2006 through May 31, 2012). This estimated total represents the sum of the DNAPL recovery volumes discussed in Section 4.2.2.1 and 4.2.2.2.

### 4.3 Regional Groundwater Flow and Contaminant Transport Model Sampling

In 2006, URS conducted groundwater sampling at selected wells throughout the region, including Sauget Area 2, Sauget Area 1, the Solutia Krummrich facility, and the Conoco Phillips property. The data from this investigation was used to update and refine the groundwater flow and contaminant transport model for the American Bottoms Aquifer (GSI, 2008b).

The following wells at Sauget Area 1 were sampled during this regional groundwater sampling program: i) upgradient wells IMW-1S, IMW-1M, and IMW-1D; ii) Site G wells EEG-107 and BR-G; iii) Site H wells EE-01, EEG-03, and BR-H; and iv) the monitoring wells surrounding the TSCA cell, which is located in the area south of Site G.

The wells selected for sampling were developed before sampling if more than 10% of the well screen was silted in. The water level and total depth of each well were measured using an interface probe. If NAPL was found in a well, the depth and thickness were also measured using the interface probe, and a disposable polyethylene bailer was used to verify the presence of NAPL.

Groundwater samples were collected using low-flow methodologies. A submersible pump equipped with disposable polyethylene tubing was lowered into the well, and the pump intake was set near the middle of the screen. Tubing from the pump was connected to a flow-through cell for measurement of pH, specific conductance, temperature, turbidity, dissolved oxygen, and ORP.

Monitoring well purging was conducted at a flow rate of 100 mL/min or lower if significant drawdown occurred. Water level measurements were recorded during purging, and purging continued until pH, specific conductance, and temperature readings stabilized over a minimum of three successive flow-through cell volumes or one hour had elapsed and the data was indicative of groundwater from the formation, whichever occurred first. Immediately following purging, groundwater samples were collected at a flow rate of no more than 0.5 L/minute using the same pump used for purging.

The groundwater samples were shipped to the lab for analysis of VOCs, SVOCs, herbicides, metals, ammonium, and several geochemical parameters, which included methane, nitrate, carbon dioxide, alkalinity, sulfate, manganese, chloride, ethane, ethane, and total organic carbon. Due to the short hold time, ferrous iron was analyzed in the field using a spectrophotometer. Results of this regional groundwater sampling program are documented in the Remedial Investigation Report, Sauget Area 2 Sites, Revision 4 (URS, 2009).

#### **4.4 Vapor Intrusion Investigation**

Golder performed a vapor intrusion investigation around several structures at Sauget Area 1 during November and December 2006. The investigation was performed in accordance with a workplan approved by USEPA (Golder, 2007). The investigation included collection of soil vapor samples from three locations at the Wiese facility, three locations at the Sauget Village Hall, three locations at the Cerro Flow Products control center, and one location at a guard shack at the entrance to the Cerro truck parking area (Figure 4-7).

**Probe Installation** - The soil vapor probes were installed within fifteen feet of exterior building walls at each of the structures selected for investigation. The probes were installed using a threaded steel drive tube and were constructed of 3/16<sup>th</sup> inch diameter Teflon tubing attached to gas vapor probes. The annulus of each probe was backfilled with six inches of clean sand followed by a bentonite that then was hydrated to form a seal. The probe depths were approximately 5 ft bgs at Wiese, 11 ft bgs at Sauget Village Hall, 0.8 to 1.8 ft bgs at the Cerro control building, and 5 ft bgs at the Cerro guard shack.

A surface seal of hydrated bentonite was constructed at each vapor probe location to prevent entry of atmospheric air into the sampling tube during purging and sampling. A clear plastic tote was used as a shroud for helium leak testing, and hydrated bentonite was used to create a seal between the shroud and the ground surface.

**Purging and Leak Testing** - Each sampling point and associated tubing were purged by removing three probe volumes at a rate of 100 mL/min using a sample pump with a low-flow module. Once two probe volumes were purged from the sampling point, a third probe volume was purged during helium leak testing. Ultra-high purity helium was pumped into the clear plastic tote around the vapor probe location until a helium atmosphere was reached. The third probe volume was then purged from the sampling train while monitoring helium concentrations in purged air. Helium concentrations in the purged air from each probe were below the 5% helium detection level.

**Soil Vapor Sampling** - Following successful helium leak testing, a dedicated six-liter Summa canister and corresponding flow controller were used for sampling at each vapor probe. Each canister had a vacuum of 25 inches of mercury prior to sampling. An initial vacuum and sampling start time were recorded, and canister vacuum and general observations were noted every 10 minutes until the vacuum gauge indicated 5 inches of mercury remaining.

The vapor samples were submitted for laboratory analysis of VOCs by TO-15 Modified Hi-Lo full scan. After sampling was performed at each location, the sample tubing was pulled from the ground and the remaining hole was backfilled with bentonite.

Data validation was performed upon receipt of laboratory results. Validated analytical results, along with field notes, photo documentation, and laboratory reports, are included in the Soil Vapor Investigation Report (Golder, 2007a). Results are summarized in the table below.

Maximum Detected Concentrations of VOCs in Soil Vapor Samples at Wiese Property, Cerro, and Sauget Village Hall

Constituent	Wiese Building Maximum Concentration (ppbv)	Cerro Control Center Maximum Concentration (ppbv)	Cerro Guard House Maximum Concentration (ppbv)	Sauget Village Hall Maximum Concentration (ppbv)
Acetone	ND	12	15	43
Benzene	13,000	1.1	8.2	7.6
1,3-Butadiene	ND	0.22	2.5	4.3
2-Butanone (MEK)	ND	0.81	2.8	9.9
Butylbenzene	ND	1.7	ND	ND
Carbon disulfide	260	1.1	35	8.9
Carbon Tetrachloride	ND	ND	ND	0.15
Chlorobenzene	70,000	ND	ND	140
Chloroethane	ND	ND	0.28	ND
Chloroform	ND	4.1	ND	ND
Chloromethane	ND	0.27	0.2	0.54
Cumene	ND	ND	ND	1.4
Cyclohexane	760	1.8	16	160
1,2-Dichlorobenzene	8,100	ND	ND	0.61
1,3-Dichlorobenzene	600	ND	ND	1.5
1,4-Dichlorobenzene	6,900	ND	ND	7.5
1,1-Dichloroethane	ND	5.5	1.7	ND



1,1-Dichloroethene	ND	0.26	ND	ND
cis-1,2-Dichloroethene	2,800	25	ND	ND
trans-1,2-Dichloroethene	78	ND	ND	ND
Ethanol	ND	1.7	ND	35
Ethyl Acetate	ND	10	ND	ND
Ethylbenzene	680	0.87	1.3	2.9
4-Ethyltoluene	16	0.3	0.49	2.7
Freon 11	ND	0.27	0.28	0.38
Freon 12	ND	0.57	0.49	0.56
Freon 113	ND	0.18	0.2	0.15
Heptane	650	2	7.1	18
Hexane	2,200	3.8	25	140
Methylene Chloride	ND	ND	ND	44
Naphthalene	3,200	ND	21	ND
4-Methyl-2-pentanone	ND	0.23	0.61	ND
2-Propanol	ND	1.0	ND	2.8
Propylbenzene	ND	ND	0.14	0.79
Styrene	ND	ND	0.22	0.66
1,1,2,2-Tetrachloroethane	ND	0.036	ND	ND
Tetrachloroethene	5,700	31	0.28	1.6
Toluene	7,200	7.7	8.7	35
1,2,4-Trichlorobenzene	170	ND	ND	ND
1,1,1-Trichloroethane	ND	9.9	3.6	ND
Trichloroethene	1,800	22	0.54	3.7
1,2,4-Trimethylbenzene	ND	0.53	0.85	3.2
1,3,5-Trimethylbenzene	ND	0.24	0.45	1
2,2,4-Trimethylpentane	4,600	ND	ND	ND
Vinyl Chloride	9,400	3	ND	0.51
m,p-Xylene	640	2.4	2	9.7
o-Xylene	210	0.59	0.83	3.3

Data from the vapor intrusion investigation were evaluated in the Vapor Intrusion HHRA (ENSR, 2009).

#### 4.5 Utility Corridor Investigation

Site H and Site I South together were known to be part of the "Sauget Landfill", which was originally used as a sand and gravel pit and then received industrial and municipal wastes from approximately 1931 to 1957. In 1949 or 1950, Queeny Avenue was relocated southwards from what is now the Cerro Flow Products facility to its present position between Site H and Site I South. Site H is connected to Site I South under Queeny Avenue.

To evaluate risks to utility workers, a subsurface investigation was performed in the utility corridor along Queeny Avenue between Sites H and I South. The investigation was performed in accordance with a USEPA-approved work plan dated March 22, 2007.

A Geoprobe rig was used to advance a total of eight boreholes along the north and south sides of Queeny Avenue. There were four boreholes on each side of the road, spaced approximately 100 feet apart (see Figure 4-8). The boreholes were advanced to the water table unless waste was encountered first. If waste was encountered, the borehole was continued to the bottom of the waste or to the water table, whichever was shallower. The total depths of the borings ranged from 12 to 16 feet bgs.

Samples were collected continuously with depth and examined for stratigraphy, discoloration, and PID headspace readings. A soil sample from the interval of one to three feet below the deepest nearby utility line was selected for laboratory analysis. If elevated PID readings were noted in soil cores from a boring, additional an additional soil sample was selected from the portion of the core with the highest PID reading. If obvious discoloration was noted in a soil core, an additional soil sample was selected from that core. All boreholes were backfilled with granular bentonite when sampling was completed.

A total of 13 soil samples were selected for laboratory analysis, including at least one sample from each boring. The samples were submitted for laboratory analysis of VOCs, SVOCs, pesticides, herbicides, cyanide, metals, PCBs, and dioxins. Field observations, data tables, boring logs, cross sections, laboratory reports, and a data validation summary are included in the Queeny Utility Corridor Investigation report (Golder, 2008).

Waste was observed in three of the four borings in the utility corridor on the south side of Queeny Avenue adjacent to Site H and two of the four borings in the utility corridor on the north side of Queeny Avenue adjacent to Site I South. Based on these observations, there is no conclusive evidence to indicate that waste does also not exist at some locations beneath Queeny Avenue between Site H and Site I South.

ENSR conducted a toxicity evaluation of the data collected in the utility corridor investigation and identified potential risks greater than  $10^{-3}$  in the utility corridor, south of Queeny Avenue, adjacent to Site H (ENSR, 2008b). Constituents with risks above  $10^{-3}$  include PCBs and 2,3,7,8-TCDD-TEQ. These wastes are therefore defined as principal threat wastes. Therefore, action will be needed to prevent exposure to the soils in the utility corridor adjacent to Site H, or to reduce the concentrations to acceptable levels.

#### **4.6 Soil to Groundwater Migration Investigation**

A soil to groundwater migration investigation was performed at Dead Creek in July 2007 in accordance with a USEPA-approved workplan dated April 27, 2007 (Golder, 2007b). The purpose of the investigation was to determine whether the concentrations of cadmium detected in creek-bottom soils could present an issue for shallow groundwater quality downgradient (west) of Dead Creek Segments C, D, E, and F. Creek bed transects with the highest cadmium concentrations in soil were selected from each creek segment for the soil to groundwater migration investigation.

**Installation of Temporary Wells** – A Geoprobe rig was used to advance four boreholes and install temporary wells at the following locations:

- Temporary well 7: Transect-T7 at Dead Creek Segment C (CSC-T7)
- Temporary well 2: Transect-T2 at Dead Creek Segment D (CSD-T2)
- Temporary well 16: Transect-T7 at Dead Creek Segment C (CSE-T16)
- Temporary well 6: Transect-T7 at Dead Creek Segment C (CSF-T6)

Each borehole was terminated approximately 5 feet below the water table. The temporary well was constructed of a ¾-inch diameter PVC riser with a 5-foot long pre-packed well screen. The well was installed inside the Geoprobe rod and the screen was pushed to at least five feet below the water table.

The rods were then slowly withdrawn from the borehole to expose the screen to groundwater. Silica sand was poured into the borehole annulus to a depth of approximately two feet above the top of the screen, and the remainder of the borehole annulus was filled with bentonite pellets.

Temporary wells T2 and T7 were located on the crest of the creek bank, approximately one to five feet from the edge of the bank. Temporary well T6 was offset approximately 150 feet west of the creek bank due to the presence of dense woods and underbrush located along the creek bank. Temporary well T16 was offset approximately 50 feet from the creek bank because an apartment complex is located along the creek at that location and there was no room for the drilling equipment between the creek and the apartment building.

**Groundwater Sampling** - Groundwater samples were collected from the four temporary wells using a low flow peristaltic pump. Purging was conducted until field parameters (pH, temperature, specific conductivity, and turbidity) had stabilized for three consecutive readings and the turbidity was approximately 10 NTUs or lower.

Two filtered samples and one unfiltered sample were collected from each location. The unfiltered sample was collected to allow measurement of total cadmium. The first filtered sample, which passed through a 10-micron in-line filter, was collected to allow measurement of colloidal cadmium concentrations. The second filtered sample, which passed through a 0.45-micron in-line filter, was collected to allow measurement of dissolved cadmium concentrations.

The temporary wells were plugged and abandoned upon completion of sampling. The groundwater samples were submitted to a laboratory and analyzed for cadmium using USEPA SW-846 Method 3550/6020. Data validation was performed following receipt of analytical results.

**Results** – Procedures and results of the study were presented in a report titled Dead Creek Soil – Groundwater Leaching Investigation (Golder, 2007b). All groundwater results, both filtered and unfiltered, were below the Illinois Class I groundwater protection standard of 0.005 mg/L. These results demonstrated that cadmium leaching from soils in the creek bottom does not represent a threat to shallow groundwater quality.

## **5.0 NATURE AND EXTENT OF CONTAMINATION**

### **5.1 Introduction**

Sections 3 and 4 summarized procedures and results of the investigation of constituents in various environmental media, including surface soil, subsurface soil / waste, groundwater, air, surface water, and sediments. All sediments were removed from Dead Creek Segments B, C, D, E, and F and Site M in 2000-2002, and all sediments exceeding RBCs were excavated from the Borrow Pit Lake in 2005-2006. Creek-bottom soils with concentrations exceeding RBCs were excavated from Creek Segments B, D, and F in 2005-2006, and an armored impermeable liner was installed throughout the entire length of Creek Segment B.

The remaining contaminant source areas at Sauget Area 1 are the disposal areas at Sites G, H, I South, and L. These disposal areas contain municipal and industrial waste materials, including crushed or partially crushed drums, drum fragments, uncontained soil and liquid wastes, wood, glass, paper, construction debris, and miscellaneous trash. There is residual DNAPL in the aquifer matrix underlying portions of Sites G, H, and I South, and the dissolution of residual DNAPL in the MHU and DHU beneath the Site G, H, and I South source areas represents an on-going source of constituents to downgradient groundwater.

Site I North and Site N are not considered to be contaminant source areas. Site I North contains inert fill materials such as bricks, pieces of concrete, large concrete slabs, rebar, sheet metal, wood, fill soil, and gravel. Site N, which is located on property formerly owned by the H. Hall Construction Company, was primarily used for disposal of construction debris. The waste materials found in Site N included soil, brick, concrete, metal, tires, and wood as well as some crushed drums, including a few that contained a pasty whitish material that could have been painting waste.

This section summarizes the nature and extent of contamination and is organized as follows:

- **Section 5.2 Source Areas**
  - 5.2.1 Soil and Waste Volume
  - 5.2.2 Soil and Waste Characterization
  - 5.2.3 Principal Threat Waste Evaluation
  - 5.2.4 DNAPL Evaluation
- **Section 5.3 Groundwater**
  - 5.3.1 Characterization at and Downgradient of Site I South
  - 5.3.2 Characterization at and Downgradient of Sites G and H
- **Section 5.4 Site Conditions after Completion of Sediment and Creek Bottom Soil Removal Actions**
- **Section 5.5 Floodplain Soil**
- **Section 5.6 Air**
  - 5.6.1 Source Area Ambient Air

### 5.6.2 Vapor Intrusion

The nature and extent of contamination at the source areas and in groundwater will be defined for nine indicator constituents, which include six VOCs, two SVOCs, and one herbicide. The six VOC indicator constituents are benzene, chlorobenzene, and a group of four chlorinated ethenes, including tetrachloroethene, trichloroethene, 1,2-dichloroethene (1,2-DCE), and vinyl chloride. The two SVOC indicator constituents are 1,4-dichlorobenzene and 4-chloroaniline, and the herbicide indicator constituent is 2,4-dichlorophenoxyacetic acid (2,4-D). Benzene, chlorobenzene, 1,4-dichlorobenzene, 1,2-DCE, vinyl chloride, and 4-chloroaniline were selected as indicator constituents because of their presence at elevated concentrations in groundwater at and downgradient of the Sauget Area 1 sites. Tetrachloroethene and trichloroethene were not found to be widespread in groundwater but were selected as indicator constituents because they are parent compounds of 1,2-DCE and vinyl chloride and were detected in subsurface soil and waste. The herbicide 2,4-D is not widespread in groundwater but was selected as an indicator constituent because it was detected in groundwater samples from beneath the Site G and Site H source areas and in several groundwater samples downgradient of Site I South.

This section includes isoconcentration cross sections (Figures 5-1 to 5-11) and isoconcentration maps (Figures 5-21 to 5-47) to illustrate the extent of the Sauget Area 1 indicator constituents in groundwater. The exceedance areas in the SHU, MHU, and DHU in the Sauget region that are shown on Figures 5-48, 5-49, and 5-50 are based on exceedances of any of 14 of the Sauget Area 2 indicator constituents, which include the nine Sauget Area 1 indicator constituents listed above plus nitrobenzene; 2,4-dichlorophenol; 2,4,6-trichlorophenol; 1,2-dichloroethane; and arsenic. Table 3-89 presents the groundwater regulatory levels (i.e., MCLs or EPA Regional Screening Levels if MCLs are not available) for the chemical constituents that were analyzed during Sauget Area 1 groundwater investigations. Tables 5-1 through 5-4 present all groundwater testing results that exceed groundwater regulatory levels for the SHU, MHU, DHU, and residential areas, respectively.

## 5.2 Source Areas

### 5.2.1 Source Area Soil and Waste Volume

Sites G, H, and I South were historically used for disposal of municipal and industrial waste. Site G was operated from some time after 1940 to 1966, and was subject to intermittent dumping thereafter until 1982, when the site was fenced. Sites H and I South were operated from the 1930s to the 1950s. Prior to the construction of Queeny Avenue in the 1940s, Sites H and I South were contiguous disposal areas. Inert material, rather than waste, was placed at Site I North to level the area for truck trailer parking.

Site L was previously used for disposal of wash water from truck cleaning operations from approximately 1971 to 1981 and was later backfilled. Site N is located on the former H.H. Hall Construction Company property and was formerly used to dispose of construction debris consisting of soil, brick, concrete, metal, tires, wood, and to a lesser degree, waste solids and drummed materials, possibly including some painting wastes.

As discussed in Section 3.2, source area investigations completed during the SSP included the review of historical aerial photographs, performance of soil-gas and magnetometer surveys, excavation of boundary trenches and advancement of borings to confirm the boundaries of the waste disposal areas. The source area investigations also included excavation of anomaly trenches to investigate whether the anomalies detected during the magnetometer surveys were associated with buried drums or tanks.

Estimated volume for each disposal area was based upon the surface area and a conservative estimate of the average waste depth determined during the SSP. Average depths were determined by reviewing the disposal area boring logs. Borings that encountered little or no waste were not used in determining average waste depths. Volumes were then estimated by multiplying the surface area by the average waste depth, and converting to cubic yards, as shown in the following table.

Estimated Sauget Area 1 Disposal Area Waste Volumes			
<u>Disposal Area</u>	<u>Disposal Area Areal Extent (Acres)</u>	<u>Average Estimated Waste Thickness (Feet)</u>	<u>Estimated Waste Volume (Cubic Yards)</u>
Site G + Site G West	3.32	20	107,000
Site H	4.87	20	157,000
Site I South	8.79	25	355,000
Site I North	5.87	6	56,800
Site L	1.08	10	17,500
Site N	3.84	16	103,000
			<u>796,000</u>

Collectively, Sites G, H, I South, I North, L and N contain an estimated 796,000 cubic yards of soil and waste. Site I South is the largest disposal area with an estimated waste volume of 355,000 cubic yards followed by Site H with 157,000 cubic yards and Site G plus G West with 107,000 cubic yards. All three of these sites were formerly used for industrial/municipal waste disposal. Estimated waste volume in Site L is much smaller, 17,500 cubic yards. Site L is a backfilled wastewater impoundment. Site N contains an estimated volume of 103,000 cubic yards, and Site I North contains an estimated volume of 56,800 cubic yards. Site N is an inactive construction debris disposal area on the former H.H. Hall Construction Company property, and Site I North is a former fill area that contains broken concrete, bricks, metal, wood, and soil.

### 5.2.2 Soil and Waste Characterization

Disposal area waste characterization investigations completed during the SSP included the performance of soil gas and magnetometer surveys, installation of test trenches and borings and collection of waste characterization samples. Waste materials encountered at Sites G, H, I South, and L consisted of municipal and industrial waste materials, including crushed or partially-crushed drums, drum fragments and remnants, uncontained solid and liquid wastes, wood, glass, paper, construction debris and miscellaneous trash. The fill material encountered at Site I North included bricks, pieces of concrete, large concrete slabs, rebar, sheet metal, other metal scrap, and wood. No evidence of drums was observed in the anomaly trench at Site I North. The fill material encountered at Site N consisted primarily of construction debris such as soil, brick, concrete, metal, tires, and wood as well as some crushed drums, including a few that contained a pasty whitish material that could have been painting waste.

Although the SSP investigation targeted potential hot spots in each disposal area, no significant residual wastes were identified during these investigations. A total of 82 crushed or partially crushed drums and drum remnants were discovered (see summary of drum inventory in Section 5.2.3.1). Only one intact drum was found; it was discovered in a test trench excavated at Site G. No surface leachate breakouts or discharges were observed at any of the disposal areas.

Soil and waste characterization results for each of the sites are discussed below.

#### 5.2.2.1 Site G

**Surface Soil** - Constituents detected in surface soil at Site G included 13 pesticides as well as PCBs, dioxins, and metals. There were no detections of VOCs, SVOCs, or herbicides. Summary statistics for Site G surface soil analytical data are included in Table 3-2. No indicator constituents were detected in surface soil at Site G.

**Subsurface Soil and Waste** – Test trenching at Site G revealed the presence of crushed or partially crushed drums and drum fragments, some of which contained waste materials. Material within one drum generated smoke when it was uncovered, indicating the presence of pyrophoric materials. Other uncontained solid wastes were encountered during trenching. One intact drum was found, which was over-packed and disposed of off-Site. Site G subsoil and waste borings encountered oily wastes and an unidentified yellow substance. Maximum PID readings ranged up to 1367 ppm for materials recovered in the waste borings. TCLP analyses indicate that materials encountered in Site G can be classified as hazardous waste exhibiting the characteristic of toxicity.

Constituents detected in subsurface soil and waste at Site G included 15 VOCs, 25 SVOCs, 1 pesticide, 1 herbicide, PCBs, and metals. Summary statistics for historical Site G subsurface soil and waste analytical data are included in Table 3-12. Detections of the indicator constituents are summarized in the table below.

Maximum, Minimum and Mean Concentrations of Indicator Constituents In Site G Subsurface Soil and Wastes

Indicator Constituents		Number of Detects	Minimum Detected Concentration (mg/kg)	Mean Detected Concentration (mg/kg)	Maximum Detected Concentration (mg/kg)
VOCs	Benzene	6	0.003	15.3	45.3
	Chlorobenzene	8	0.107	108	538
	Tetrachloroethene	8	0.009	18.8	58.6
	Trichloroethylene	4	0.762	1.94	3.85
	cis-1,2-DCE	ND	ND	ND	ND
	Vinyl Chloride	ND	ND	ND	ND
SVOCs	1,4-Dichlorobenzene	2	2.38	2.97	3.56
	4-Chloroaniline	3	5.97	81.6	231
Herbicides	2,4-D	ND	ND	ND	ND

Note: Historical data from Ecology and Environment, 1998

The greatest concentrations in subsurface soils were detected at depths between 10 to 25 feet below ground surface.

### 5.2.2.2 Site H

**Surface Soil** - Constituents detected in surface soil at Site H included 3 VOCs, 11 SVOCs, 9 pesticides, 2 herbicides, PCBs, dioxin, and metals. Summary statistics for Site H surface soil analytical data are included in Table 3-3. The only detected indicator constituent was tetrachloroethene, which was detected in one sample at a concentration of 0.017 mg/kg.

**Subsurface Soil and Waste** – Anomaly trenching in Site H revealed the presence of partial drums and drum fragments. Other materials encountered included brick, wood, plastic and other refuse. A variety of materials were encountered in Site H borings, but no specific uncontained waste substances were described in the field notes and logs. Waste materials found in six of the eight borings consisted of multicolored sludges, solids, and oily refuse underlying the fill. Maximum PID readings ranged up to 2000 ppm. Results from TCLP analyses indicate that materials encountered in Site H can be classified as hazardous waste exhibiting the characteristic of toxicity.

Constituents detected in subsurface soil and waste at Site H included 13 VOCs, 32 SVOCs, 3 pesticides, PCBs, 18 metals, and total cyanide. Summary statistics for historical Site H subsurface soil and waste analytical data are included in Table 3-13. Detections of the indicator constituents are summarized in the table below.

**Maximum, Minimum and Mean Concentrations of Indicator Constituents In Site H Wastes**

Indicator Constituents		Number of Detects	Minimum Detected Concentration (mg/kg)	Mean Detected Concentration (mg/kg)	Maximum Detected Concentration (mg/kg)
VOCs	Benzene	7	0.004	15.2	61.3
	Chlorobenzene	6	0.024	97.6	452
	Tetrachloroethene	1	5.65	5.65	5.65
	Trichloroethylene	1	0.01	0.01	0.01
	cis-1,2-DCE	ND	ND	ND	ND
	Vinyl Chloride	ND	ND	ND	ND
SVOCs	1,4-Dichlorobenzene	5	0.062	6,320	30,600
	4-Chloroaniline	ND	ND	ND	ND
Herbicide	2,4-D	ND	ND	ND	ND

**Note:** Historical data from Ecology and Environment, 1998

Based upon results of previous investigations (Ecology and Environment, 1998), contaminant concentrations were generally higher in the central and northern portions of the site compared to the southern portion. Highest concentrations were generally from samples collected from 10 to 25 feet BGS.



### 5.2.2.3 Site I South

**Surface Soil** – Constituents detected in surface soil at Site I South included 23 SVOCs, 15 pesticides, 1 herbicide, PCBs, dioxin, and metals. Summary statistics for Site I South surface soil analytical data are included in Table 3-4A. The detections of indicator constituents included one detection of 1,4-dichlorobenzene at a concentration of 0.046 mg/kg and two detections of 4-chloroaniline with a maximum concentration of 18 mg/kg.

**Subsurface Soil and Waste** – Crushed or partially crushed drums and drum fragments, some containing waste materials, were found in the Site I South anomaly trench. Material within some of the drums was described as a solid, yellowish material. Other uncontained solid wastes were encountered during trenching, including contents leaking out of broken drums. Black soil, bricks, wood, and metal scraps were also encountered in the anomaly trenches. Materials encountered in Site I South borings included uncontained solid wastes described as white and metallic shiny substances. Maximum PID readings ranged up to 2000 ppm for materials recovered in the waste borings. TCLP analyses indicate that materials encountered in Site I South can be classified as hazardous waste exhibiting the characteristic of toxicity.

Constituents detected in historical subsurface soil and waste samples at Site I South included 13 VOCs, 28 SVOCs, 3 pesticides, 1 herbicide, PCBs, metals, and total cyanide. Summary statistics for historical Site I subsurface soil and waste analytical data are included in Table 3-14. Detections of the indicator constituents are summarized in the table below.

**Maximum, Minimum and Mean Concentrations of Indicator Constituents In Site I South Wastes**

Indicator Constituents		Number of Detects	Minimum Detected Concentration (mg/kg)	Mean Detected Concentration (mg/kg)	Maximum Detected Concentration (mg/kg)
VOCs	Benzene	10	0.023	3.81	24.1
	Chlorobenzene	12	0.010	34.7	127
	Tetrachloroethene	5	0.612	2.57	5.27
	Trichloroethylene	2	0.648	2.23	3.81
	cis-1,2-DCE	ND	ND	ND	ND
	Vinyl Chloride	ND	ND	ND	ND
SVOCs	1,4-Dichlorobenzene	8	1.60	255	1,840
	4-Chloroaniline	1	43.2	43.2	43.2
Herbicide	2,4-D	ND	ND	ND	ND

Note: Historical data from Ecology and Environment, 1998

Waste material was noted in several borings in Site I South at depths below the water table and consisted of oily sand, clay, wood and cinders mixed with refuse. Contamination was detected at depths extending to 38 feet bgs.

#### 5.2.2.4 Site I North

**Surface Soil** – Constituents detected in surface soil at Site I North included 1 VOC, 13 SVOCs, 15 pesticides, 2 herbicides, PCBs, dioxin, and metals. Summary statistics for Site I North surface soil analytical data are included in Table 3-4B. No Sauget Area 1 indicator constituents were detected in surface soil at Site I North.

**Subsurface Soil and Waste** – Bricks, pieces of concrete, large concrete slabs, rebar, sheet metal, other metal scrap, and wood were found in the Site I North anomaly trench. Maximum PID readings ranged up to 21 ppm for materials recovered in the two fill area borings at Site I North. Concrete pieces were observed at shallow depths in both borings.

One soil boring was drilled at Site I North during the historical investigation by Ecology and Environment, and the boring log indicated that there was four feet of fill consisting of sandy clay and a mixture of crushed limestone, gravel, and concrete fragments (Ecology and Environment, 1988). No soil samples from this boring were submitted for laboratory analysis.

#### 5.2.2.5 Site L

**Surface Soil** - Constituents detected in surface soil at Site L included 1 VOC, 19 SVOCs, 9 pesticides, 1 herbicide, PCBs, dioxin, metals, and total cyanide. Summary statistics for Site L surface soil analytical data are included in Table 3-5. No indicator constituents were detected in surface soil at Site L.

**Subsurface Soil and Waste** – Anomaly trenching in Site L revealed the presence of crushed or partially crushed drums and drum fragments, some containing waste materials. A black tar-like substance was noted to be leaking from several drums. Other uncontained solid wastes were encountered during trenching. Other materials encountered in Site L trenching include bricks, rags, small pieces of concrete, and various other refuse. Discovery of crushed or partially crushed drums indicates that Site L was used for more than disposal of wash water from truck-cleaning operations. A variety of fill materials were encountered in Site L borings, but no specific uncontained waste substances were described in the field notes and logs. Maximum PID readings ranged up to 728 ppm for materials recovered in the waste borings. TCLP analyses did not indicate that materials encountered in Site L exhibited the characteristic of toxicity.

Constituents detected in subsurface soil and waste at Site L included 10 VOCs, 35 SVOCs, 1 herbicide, PCBs, metals, and total cyanide. Summary statistics for historical Site L subsurface soil and waste analytical data are included in Table 3-15. Detections of the indicator constituents are summarized in the table below.

**Maximum, Minimum and Mean Concentrations of Indicator Constituents In Site L Wastes**

Indicator Constituents		Number of Detects	Minimum Detected Concentration (mg/kg)	Mean Detected Concentration (mg/kg)	Maximum Detected Concentration (mg/kg)
VOCs	Benzene	5	0.004	2.01	5.70
	Chlorobenzene	8	0.012	1.25	5.30
	Tetrachloroethene	ND	ND	ND	ND
	Trichloroethylene	ND	ND	ND	ND

	cis-1,2-DCE	ND	ND	ND	ND
	Vinyl Chloride	ND	ND	ND	ND
SVOCs	1,4-Dichlorobenzene	9	0.018	23.4	100
	4-Chloroaniline	6	0.043	98.7	270
Herbicide	2,4-D	ND	ND	ND	ND

Note: Historical data from Ecology and Environment, 1998

Contaminants in Site L were generally detected at depths ranging from 5 to 15 feet bgs.

#### 5.2.2.6 Site N

**Surface Soil** - Constituents detected in surface soil at Site N included 13 SVOCs, 7 pesticides, 1 herbicide, PCBs, dioxin, and metals. Summary statistics for Site N surface soil analytical data are included in Table 3-6. No indicator constituents were detected in surface soil at Site N.

**Subsurface Soil and Waste** – Site N is located on property formerly owned by the H. Hall Construction Company and was primarily used for disposal of construction debris. The construction waste materials encountered in Site N trenches included bricks, concrete debris, rebar, metal pipes and cables, sheet metal, railroad ties, scrap lumber, telephone poles, crushed and partially crushed drums and drum lids, plastic sheeting, rags, scrap tires, various other refuse, and fill soil.

Some of the crushed or partially crushed drums and drum fragments contained waste materials. Whitish and pasty white substances were noted in several of the crushed and partially crushed drums. PID readings inside the excavated drums ranged up to 870 ppm. Other uncontained solid wastes were encountered during trenching, including a whitish material that discharged from an interior trench. The pasty whitish material noted in the damaged drums and in the interior trench could have been painting waste, which would be consistent with the former use of Site N for disposal of construction debris.

Materials encountered in Site N borings included an unidentified green material. Maximum PID readings ranged up to 65.7 ppm for materials recovered in the waste borings. TCLP analyses did not indicate that materials encountered in Site N exhibited the characteristic of toxicity.

A limited amount of historical sampling and analytical data are available for Site N (Ecology and Environment 1998). This 1998 data indicated that total VOC concentrations ranged up to 0.014 mg/kg in the two subsurface soil and waste samples collected at Site N. Total SVOCs were detected at a maximum concentration of 2.28 mg/kg in the two subsurface soil and waste samples. Pesticides and PCBs were not detected in either of the samples. Constituents detected in the subsurface samples at Site N included 4 VOCs and 8 SVOCs. Summary statistics for historical Site N subsurface soil and waste analytical data are included in Table 3-16. There were no detections of the indicator constituents in the two samples.

### 5.2.3 Principal Threat Waste Evaluation

Principal threat wastes are defined in a USEPA fact sheet (USEPA, 1991).

*Principal threat wastes are those source materials that are considered to be highly toxic or highly mobile that cannot be reliably contained or would present a significant threat to human health or the environment should exposure occur. They include liquids and other highly mobile materials (e.g., solvents) or materials having high concentrations of toxic compounds. No threshold level of toxicity/risk has been established to equate to principal threat. However, where toxicity and mobility of source material combined to pose a potential risk of  $10^{-3}$  or greater, generally treatment alternatives should be evaluated.*

The USEPA fact sheet presents several examples of principal threat wastes.

*Wastes that generally will be considered to constitute principal threats include, but are not limited to:*

- *Liquids – waste contained in drums, lagoons or tanks, free product (NAPLs) floating on or under groundwater (generally excluding groundwater) containing contaminants of concern.*
- *Mobile source material – surface soil or subsurface soil containing high concentrations of contaminants of concern that are (or potentially are) mobile due to wind entrainment, volatilization (e.g., VOCs), surface runoff, or sub-surface transport.*
- *Highly toxic source material – buried drummed non-liquid wastes, buried tanks containing non-liquid wastes, or soils containing significant concentrations of highly toxic materials.*

The following sections discuss the results of the principal threat waste evaluation for liquids, mobile source material, and toxicity.

#### 5.2.3.1 Principal Threat Waste Evaluation - Liquids

Pooled non-aqueous phase liquids (NAPLs) are source materials and may be considered principal threat waste liquids. The DNAPL Characterization and Remediation Study (GSI, 2006c) identified wells containing pooled NAPLs and delineated the extent of residual DNAPL in the subsurface beneath the source areas. Procedures and results of the DNAPL Characterization and Remediation Study were presented in Section 4.2.1. Section 5.2.4 summarizes the nature and extent of pooled and residual DNAPL.

Buried drums and drum fragments were encountered during source area investigations at Sites G, H, I South, L, and N. No drums or drum fragments were encountered during investigations at Site I North. No underground tanks were found during any of these investigations. GSI prepared a report, "Evaluation of Buried Drums", to summarize available information regarding the buried drums and to evaluate whether

the drums represent principal threat material. The following paragraphs summarize the information that was presented in that report (GSI, 2006b).

**Summary of Source Area Investigations** – The source area investigations conducted by O'Brien & Gere in 1999-2000 included the following tasks: i) review of aerial photos, topographic maps, and topographic survey data to obtain information regarding fill area boundaries; ii) excavation of boundary trenches to confirm the horizontal limits of the fill areas; iii) a soil gas survey at and near each fill area; iv) waste sampling to characterize the fill materials; iv) a magnetometer survey at each fill area to identify magnetic anomalies potentially indicative of buried tanks or drums; and v) anomaly test trenching at an interior location in each fill area to look for buried tanks or drums. Sections 3.2.1 and 3.2.2 of this report provide a detailed description of procedures and results. Boundary test trench locations and anomaly test trench locations are shown on Figures 3-1 through 3-5.

Anomaly test trench locations were identified using a combination of magnetic anomalies, aerial photo analysis, and soil gas and groundwater data. One test trench was excavated per site at Sites G, H, L, and N. Two test trenches were excavated at Site I (one each at Site I South and North). Test trenches were performed at the largest magnetic anomaly found that coincided with the following, as applicable: i) possible drum/tank disposal locations identified by analysis of historical aerial photos; ii) an area of high VOC concentrations in soil gas; iii) an area of high groundwater concentration identified in the 1998 Ecology and Environment Data Report; or iv) major magnetic anomalies noted in the 1988 geophysical survey (Ecology and Environment, 1988). The trenches were advanced until evidence as to the source of the anomaly was found.

The source area investigations conducted by TetraTech (Tetra Tech 2003a, 2003b, 2003c) included excavation of exploratory trenches and collection of waste and soil samples at Sites H, I South, L, and N. Groundwater samples were collected at Sites I South, L, and N. Section 4.1 of this report provides a detailed description of procedures and results of the Tetra Tech investigations. Trench locations are shown on Figures 4-1 and 4-2.

**Inventory of Buried Drums** – The Evaluation of Buried Drums report (GSI, 2006b) included a table with a detailed inventory of the drums and drum fragments discovered during test trenching based on GSI's review of field notes and photos from the test trenching conducted by O'Brien & Gere in 1999-2000 the site investigation reports prepared by Tetra Tech (Tetra Tech, 2003a, 2003b, and 2003c). For each trench location, the drum inventory table documents the number of drums observed, descriptive information regarding drum condition and drum contents, where available, GSI's interpretation regarding whether or not the observed drums contained liquids constituting principal threat waste, and detailed references to the field notes and photos. As documented in the drum inventory table (GSI, 2006b), the total number of drums observed at each site was as follows:

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**Total Number of Drums Observed in Test Trenches at Sites G, H, I South, L, and N**

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- Site G            15
- Site H            None (only fragments and lids)
- Site I South    14

• Site L	22
• Site N	31
<b>Total:</b>	<b>82</b>

No drums or drum fragments were encountered during investigations at Site I North. Except for a single relatively intact drum at Site G, the buried drums encountered during test trenching were found to be crushed, split, heavily damaged, or without a lid. Some damaged drums contained solid contents, while others were empty. One damaged drum encountered at Site I and six damaged drums at Site L contained tar-like substances or other high viscosity liquids. In GSI's opinion, tar-like substances or other high viscosity liquids would not be considered liquids constituting principal threat wastes. These materials are not highly mobile and would tend to be retained in the fine-grained soils that characterize the shallow hydrogeologic unit. The following paragraphs discuss the key findings regarding buried drums at Sites G, H, I South, L, and N.

**Site G** – A total of 15 drums were found in the trenches at Site G. With the exception of one relatively intact drum, the drums found in the trenches at Site G were crushed, split, heavily damaged, or without a lid. The one relatively intact drum, which contained solid materials, was overpacked and removed. All the other drums described and photographed at this site contained solid materials or were empty. One damaged drum that contained solid materials began to smoke when it was uncovered.

**Site H** - The only evidence of drums in the trenches at Site H was two partial drums along with drum fragments and lids.

**Site I South** - A total of 14 damaged drums were found at Site I South. Ten drums were found in the interior trench excavated in 2000. Five of these drums were described in the field notes as “fairly intact,” but further investigation of the drum that appeared to be in the best shape showed that it had two large holes on the bottom side. The five “fairly intact” drums contained a solid material that resembled wood.

A total of four drums were found in four exploratory trenches excavated by Tetra Tech in July 2002. One drum that was in “very poor condition” contained a “nonvolatile tar-like substance.” A waste sample of this substance was submitted for laboratory analysis of VOCs, SVOCs, metals, pesticides, and PCBs. As noted by Tetra Tech (Tetra Tech, 2003a), analytical results did not exceed USEPA Risk-Based Concentrations (RBCs).

**Site L** - A total of 22 damaged or crushed drums were found in two trenches at Site L. Drums were found in the Interior Trench excavated by O'Brien & Gere in February 2000. The field notes described 18 damaged drums that were found in this trench. Four of the drums appeared to be leaking a “black tar-like substance,” and one drum appeared to be leaking a “tanish-brown flowable material.” The high viscosity of these materials would make them relatively immobile in the fine-grained soils of the shallow hydrogeologic unit. Therefore, these high viscosity materials would not constitute principal threat waste.

The end of the field notes for the Interior Trench excavated by O'Brien & Gere included a statement that “additional drums may be buried in the southside wall.” This possibility was investigated by USEPA in March 2003 at trench T1, which was immediately south of the location of the February 2000 Interior Trench (see Figure 4-1). Four damaged drums were found in the western part of trench T1. One of the four damaged drums was reported to contain a black oily liquid and a yellowish semi-solid the

consistency of paint. Waste samples were collected from this drum and another drum that contained a white solid with a mothball-like odor. Analytical results indicate that these waste materials contained relatively low concentrations of VOCs and SVOCs (Tetra Tech, 2003b). The drums from trench T1 are not principal threat drums, based on the physical state of the wastes (solids or high-viscosity liquids) and the relatively low concentrations of VOCs and SVOCs detected in the materials. The results from trench T1 confirm that there is no cache of buried drums of liquid wastes in the area south of the February 2000 Interior Trench.

**Site N** – Site N had the most drums of any site, 31, but all were found to be crushed or badly damaged. White material was visible in or on several of the drums. One of the crushed drums contained some paint-like sludge. The white material and paint-like sludge could have been painting waste, which would be consistent with the former use of Site N for disposal of construction debris. Site N is located on property formerly owned by the H. Hall Construction Company.

It is GSI's opinion that none of the drums found at Sites G, H, I South, L, and N contained liquids constituting principal threat waste.

**Review of Historical Aerial Photos** – GSI reviewed historical aerial photos to look for evidence of drums or tanks. The photos came from two sources: the 1988 Ecology and Environment report titled "Expanded Site Investigation, Dead Creek Project Sites at Cahokia/Sauget, Illinois"; and a collection of historical aerial photos taken from an October 2002 report prepared by Mary Sitton for the Department of Justice. GSI received digital copies of the historical aerial photos for independent analysis but did not read or review the Department of Justice report.

Historical aerial photos included in the 1988 Ecology and Environment report show the Cahokia/Sauget area for the years 1937, 1950, 1955, 1962, 1973, 1978, and 1985 (a total of 7 aerial photos). In its analysis of the aerial photos, Ecology and Environment did not mention observations of large caches of drums on any of the photos. The collection of historical aerial photos taken from the Department of Justice report included a total of 19 aerial photos from the period 1940 to 1993. GSI examined these photos and saw no large caches of drums.

**Key Findings** – The key findings from "Evaluation of Buried Drums" (GSI, 2006b) were as follows:

- None of the buried drums found during test trenching at Sites G, H, I South, L, and N contained liquids constituting principal threat waste.
- There do not appear to be large caches of drums containing liquid wastes or highly mobile source material in the areas previously investigated for principal threat material at Sites G, H, I South, L, and N.
- No large caches of drums were seen in historical aerial photos.

#### **5.2.3.2 Principal Threat Waste Evaluation – Mobile Source Material**

Mobile source material can be principal threat waste. Mobile source material includes surface soil or subsurface soil containing high concentrations of contaminants of concern that are mobile or potentially

mobile due to wind entrainment, volatilization, surface runoff, or sub-surface transport (EPA, 1991). Based on existing surface conditions at the Sauget Area 1 sites, there is no significant risk of wind entrainment, volatilization, or surface runoff of high concentrations of contaminants of concern from surface soil or subsurface soil.

Pooled DNAPL is a source material and may be considered a principal threat waste liquid. However, DNAPL trapped by capillary forces in pore spaces within the unsaturated zone or aquifer matrix (residual DNAPL) is not considered a mobile source material. Typically, the majority of DNAPL mass migrating from a source area is trapped by capillary forces within the alluvial aquifer pore space as residual DNAPL in small, discrete blobs and ganglia. Residual DNAPL is not believed to be mobile, and is expected to dissolve relatively slowly. As stated by Pankow and Cherry (1996), "Once the release of liquid waste into the subsurface ceases, subsurface movement of DNAPL also ceases soon thereafter, perhaps within weeks or months...". With industrial disposal ceasing in 1957 at Sites H and I and in 1966 at Site G, residual DNAPL at these sites is not likely to be mobile.

Although residual DNAPL is not itself a mobile source material, it is considered to be a significant source of on-going contamination to groundwater.

#### **5.2.3.3 Principal Threat Waste Evaluation – Highly Toxic Source Materials**

Another type of principal threat waste is highly toxic source material, such as buried drummed non-liquid wastes, underground tanks containing non-liquid wastes, or soils containing significant concentrations of highly toxic materials (EPA, 1991).

ENSR conducted a toxicity evaluation to identify whether waste materials and soils within Sites G, H, I, L, and N may be defined as principal threat wastes. Results of the evaluation were presented in the Disposal Area Waste Toxicity Evaluation (ENSR, 2008).

**Disposal Area Waste Toxicity Evaluation** - Because the wastes are present in the subsurface, ENSR's evaluation focused on potential risks in Sites G, H, I, and L for a construction worker potentially exposed to waste in the subsurface via ingestion, dermal contact, and inhalation of dusts derived from subsurface soil. The data were evaluated to determine whether wastes present potential risks to human health greater than a cancer risk level of  $10^{-3}$ . Because the sites are known areas of waste disposal, appropriate safeguards (i.e., air monitoring and personal protective equipment) would likely be used when excavating in waste areas. However, the use of such safeguards was not assumed when identifying the exposure factors used in the risk assessment.

The evaluation was conducted on analytical data from subsurface soil and waste samples collected during the following work programs:

- EE/CA and RI/FS waste characterization (O'Brien & Gere, 2001; Ecology and Environment, 1998)
- DNAPL investigation (GSI, 2006c)
- Supplemental investigations (Tetra Tech, 2003a, 2003b, 2003c)



The dataset from the EE/CA and RI/FS waste characterization was evaluated in the Human Health Risk Assessment (ENSR, 2001), and all potential risks from ingestion, dermal contact, and inhalation of surface soil were below a cancer risk of  $10^{-3}$ , which indicated that these materials are not principal threat wastes. A review of dose-response factors was performed in 2008 as part of ENSR's evaluation to ensure that significant changes had not occurred which would elevate potential risks above  $10^{-3}$ . The updated dose-response assessment did not result in potential risks above  $10^{-3}$  (ENSR, 2008).

The dataset from the DNAPL Characterization and Remediation Report (GSI, 2006c) and the dataset from the supplemental investigations (Tetra Tech, 2003a, b, c) were summarized and evaluated in the Disposal Area Waste Toxicity Evaluation (ENSR, 2008). The samples collected during the DNAPL investigation that were from within the site boundaries and collected from the thickness of the fill were included in the evaluation. The samples collected during the DNAPL investigation that taken were from within the site boundaries and that were collected from depths greater than the fill thickness were not included in the evaluation. In addition, surface soil samples and all samples collected from outside the site boundaries were not included in the evaluation.

A toxicity screen was performed on the datasets in accordance with USEPA Region 5 guidance (USEPA, 1998a) and IEPA regulations (IEPA, 1998). The constituents that had maximum detected concentrations greater than the screening levels were identified as Constituents of Potential Concern (COPCs) and were carried through the quantitative risk assessment process.

Toxicity information was obtained for the oral and inhalation routes of exposure for the COPCs classified by USEPA as potential carcinogens for these routes of exposure. Oral toxicity values were also used to assess dermal exposures, with appropriate adjustments. Exposure dose equations were used to obtain potential exposure doses for each COPC via each route/pathway by which the receptor is assumed to be exposed. As noted above, the potential exposure scenarios were for an on-site construction/utility worker potentially exposed to COPCs in subsurface soil and waste via incidental ingestion and dermal contact, and via inhalation of particulates suspended during excavation activity.

Total potential carcinogenic risk to construction worker was found to be  $8.9 \times 10^{-6}$  for the dataset from the DNAPL investigation and  $1 \times 10^{-4}$  for the dataset from the supplemental investigations performed by Tetra Tech. These values are below USEPA's principal threat waste threshold of  $1 \times 10^{-3}$ .

**Utility Corridor Evaluation** – Site H at one time was connected to Site I South and together they were known to be part of the Sauget Monsanto Landfill, which operated from approximately 1931 to 1957. To evaluate risks to utility workers, a subsurface investigation was performed in the utility corridor along Queeny Avenue between Sites H and I South (Golder, 2008).

ENSR conducted a toxicity evaluation of the data collected in the utility corridor investigation and identified potential risks greater than  $10^{-3}$  in the utility corridor, south of Queeny Avenue, adjacent to Site H (ENSR, 2008). Constituents with risks above  $10^{-3}$  include PCBs and 2,3,7,8-TCDD-TEQ. These wastes are therefore defined as principal threat wastes. Therefore, action will be needed to prevent exposure to the soils in the utility corridor adjacent to Site H, or to reduce the concentrations to acceptable levels.

## 5.2.4 DNAPL Evaluation

### 5.2.4.1 Residual DNAPL

The DNAPL characterization and remediation study, which was discussed in Section 4.2.1.3, included soil sampling and testing at 19 piezometer locations. One objective of the DNAPL characterization and remediation study was to determine the volume of fill materials and aquifer matrix containing residual DNAPL.

Soil sampling and testing and core testing were conducted to obtain data that could be used to estimate the volume of fill materials and aquifer matrix containing residual DNAPL. A total of 199 soil samples from the unsaturated zone and aquifer matrix were submitted for laboratory analysis of VOCs and SVOCs. A total of 16 undisturbed frozen cores were submitted for laboratory testing of pore fluid saturations and physical properties and for evaluation of DNAPL mobility using a modified centrifuge test procedure.

Three methods were considered for estimating the volume of fill materials and aquifer matrix containing residual DNAPL, as described below.

**Equilibrium Partitioning** - The first method was to compare detected soil concentrations with concentrations that would be expected based on equilibrium partitioning from a DNAPL sample. This method, which is detailed in the 1992 U.S. EPA publication 93554-07FS ("Estimating Potential for Occurrence of DNAPL at Superfund Sites"), uses a partitioning coefficient ( $K_d$ ) to convert the effective solubility of contaminants to sorbed concentration (USEPA, 1992). Using this method, there is potential for DNAPL in a soil sample if constituents that are detected in the DNAPL sample are present in the soil sample at sorbed concentrations that exceed calculated equilibrium partitioning values.

The soil analytical data for VOCs and SVOCs indicates that the Sauget Area 1 DNAPL source materials were very heterogeneous from a chemical perspective. However, BR-I was the only location where DNAPL could be sampled and analyzed. Because of insufficient knowledge of DNAPL mole fraction composition across the Sauget Area 1 sites, the equilibrium partitioning method was not considered a reliable method for determining the presence or absence of DNAPL in soil at Sauget Area 1.

**Pore Fluid Saturation Data** - The second potential method was to compare pore fluid saturation results from core testing with total VOC and total SVOC analytical data from soil samples. NAPL pore fluid saturations for fifteen undisturbed core samples from Sauget Area 1 were plotted against concentrations of total VOCs plus total SVOCs for the soil samples closest in depth to the undisturbed cores. The overall correlation was poor ( $r^2 < 0.5$ ), indicating that this method could not be applied accurately. The poor correlation could be a result of the heterogeneous nature of the DNAPL source materials at Sauget Area 1.

**Soil Core Field Screening Results** - The third method, and the one that was selected for determining volume of residual DNAPL at Sauget Area 1, was to use a combination of visual indicators of NAPL presence and laboratory data for total VOCs and total SVOCs. Either the visual presence of NAPL in a core sample, or a positive indicator from the Sudan IV vial test kits, were used to determine the presence

of NAPLs in a soil boring. However, some locations where NAPL was indicated had very low concentrations of total VOCs and total SVOCs, and thus would probably not represent significant on-going sources of constituents to site groundwater. Therefore a further classification was used, where NAPL in soil (as indicated based on field screening of cores) was classified as “low-strength” NAPL if both total VOC and total SVOC concentrations in soil were less than 1 mg/kg. This “low-strength” NAPL in soil was excluded from the volume of residual DNAPL. NAPL in soil (as indicated based on field screening of cores) was classified as “moderate to high-strength” NAPL and was included in the volume of residual DNAPL if either total VOC or total SVOC concentrations in soil were greater than or equal to 1 mg/kg.

**Volume Estimates** - DNAPL areas were determined for the SHU, MHU, and DHU and are presented in the DNAPL Characterization and Remediation Report (GSI, 2006c). Borings with “low-strength” NAPL were excluded from the DNAPL areas, and borings with “moderate to high-strength” NAPL were included in the DNAPL areas.

For the fill / SHU, two separate DNAPL areas were defined, with a total area of approximately 15 acres (see Figure 17 of the DNAPL Characterization and Remediation Report, GSI, 2006c). Assuming a thickness of 30 ft, the volume of residual DNAPL for the fill/SHU was originally estimated to be 750,000 yd<sup>3</sup>. The DNAPL area in the Fill / SHU at Sites G, H, and I South has since been reduced from 15 acres to 13.6 acres based on the revised Site G fill area boundary shown on Figure 5-1A. Assuming a thickness of 30 ft and an area of 13.6 acres, the revised volume of residual DNAPL for the fill/SHU is estimated to be 660,000 yd<sup>3</sup>.

The MHU and DHU both had DNAPL areas of approximately 8 acres (see Figure 5-1B), and a combined volume of aquifer matrix with residual DNAPL of 950,000 yd<sup>3</sup> (assuming thickness of 40 feet for the middle hydrogeologic unit and 35 feet for the deep hydrogeologic unit). As shown on Figure 5-1B residual DNAPL is present in the MHU and DHU underlying portions of Sites G, H, and I South. There was no indication of the presence of residual DNAPL in the MHU and DHU beneath Site L, based on results of the DNAPL boring A1-04, which is located in the center of Site L.

The total volume was originally estimated at 1,700,000 yd<sup>3</sup> based but has been revised to 1,620,000 yd<sup>3</sup> based on the revised DNAPL area in the fill / SHU at Site G. These estimates were based on the assumption that the entire thickness of the shallow, middle, or deep hydrogeologic unit is affected by DNAPL if any interval within the unit shows evidence of DNAPL. Therefore, the value of 1,620,000 yd<sup>3</sup> represents an upper-bound estimate of the volume of fill and aquifer matrix with residual DNAPL. However, this conservative estimate is appropriate for planning purposes when evaluating the feasibility of various DNAPL treatment technologies for the Sauget Area 1 Sites.

**Alternative Volume Estimates** - As requested by USEPA, an alternative estimate of the volume was calculated by applying the estimated thickness of DNAPL-affected soil and aquifer matrix observed in each boring to a designated area surrounding each boring (see Figures 20, 21, and 22 of the DNAPL Characterization and Remediation Report, GSI, 2006c). The resulting volumes were then summed to obtain DNAPL-affected volumes for the SHU, MHU, and DHU. For the fill / SHU, the estimate thickness of DNAPL-affected media ranges from 5 to 25 feet across a total area of approximately 15 acres, and the calculated volume of DNAPL-affected media is approximately 420,000 yd<sup>3</sup>. For the MHU, the estimated thickness of DNAPL-affected aquifer matrix ranges from 20 to 40 feet across a total area of approximately

8 acres, and the calculated volume of DNAPL-affected aquifer matrix is approximately 400,000 yd<sup>3</sup>. For the DHU, the estimated thickness of DNAPL-affected aquifer matrix ranges from 10 to 45 feet across a total area of approximately 8 acres, and the calculated volume of DNAPL-affected aquifer matrix is approximately 350,000 yd<sup>3</sup>. Using this alternate approach, the total volume of fill and aquifer matrix affected by residual DNAPL is approximately 1,200,000 yd<sup>3</sup>.

#### **5.2.4.2 Pooled DNAPL**

As discussed in Section 4.2.1.3, well surveys for LNAPL and pooled DNAPL were performed in 2004-2005 at 57 existing wells and at the 19 piezometers installed during the DNAPL characterization and remediation study. Well survey results indicate that pooled DNAPL is not widespread at Sauget Area 1.

At Site I South, the presence of pooled DNAPL was confirmed at bedrock well BR-I and an adjacent DNAPL piezometer, A1-19, which is located 10 feet from BR-I. Recovery tests indicate that BR-I is a low-yield well. After fluids stored in the 4-inch diameter PVC casing were pumped out, the yield stabilized at approximately 0.05 gpm of total fluids at a drawdown greater than 100 ft below the static water level. After each recovery test, it took several days for the water level in BR-I to return to static conditions. Weekly DNAPL recovery at BR-I for 15 weeks resulted in recovery of 299 gallons of total fluids, including approximately 49 gallons of DNAPL. This is equivalent to an average DNAPL recovery rate of 3.3 gallons per week, or 0.5 gallons per day. DNAPL recovery has been performed at BR-I every other week as an interim remedial measure since October 2008.

At Site G, some evidence of pooled DNAPL was noted during NAPL surveys at well BR-G, but no DNAPL was recovered during three separate recovery tests performed at BR-G. Therefore, recovery of DNAPL by pumping at BR-G does not appear feasible.

Also at Site G, results of the NAPL survey performed in May 2004 indicated the presence of LNAPL in well EE-11, which is screened in the SHU. LNAPL was recovered during a recovery test performed in May 2004, but a subsequent recovery test performed in October 2004 recovered only small globs of LNAPL. Therefore, further recovery of LNAPL at EE-11 by pumping does not appear feasible.

There was no indication of pooled DNAPL in any of the wells or piezometers at Site H or Site L.

### **5.3 Groundwater at and Downgradient of the Source Areas**

Groundwater flowing beneath Sauget Area 1 ultimately discharges to the Mississippi River, approximately 5,700 feet downgradient of its western boundary. Groundwater in the alluvial aquifer underlying Sauget Area 1 flows west and northwest toward the Mississippi River at an estimated velocity of 29.6 feet/year in the SHU and 296 feet/year in the MHU/DHU (assuming a porosity of 0.35). Groundwater is the most important migration pathway from the Sauget Area 1 source areas because it has the potential to discharge site-related constituents to the Mississippi River. Potential impact could result from groundwater discharge into the river if the constituents detected in groundwater downgradient of the Sauget Area 1 source areas migrate that far. Part of the Sauget Area 1 plume is intercepted by the GMCS at Sauget Area 2 Site R.

Review of groundwater data collected during the SSP revealed that the distributions of VOCs and SVOCs downgradient of Site I South and Sites G, H and L were representative of the extent of chemical constituents present above regulatory levels. Generally speaking, herbicide and pesticide distributions parallel the VOC and SVOC data. Concentrations of PCBs, dioxin TEQs and metals occur sporadically and at comparatively low concentrations both upgradient and downgradient of disposal areas, throughout the aquifer saturated thickness. Therefore, the summary of the downgradient groundwater investigation presented in Section 3.3.2 focused on VOCs and SVOCs. The summary of groundwater conditions beneath the source areas presented in Section 3.2.6 also focused on VOCs and SVOCs because they are good indicators of contaminant transport at Sauget Area 1.

This section uses summary statistics, isoconcentration cross sections, and isoconcentration maps to illustrate the extent of the nine Sauget Area 1 indicator constituents in groundwater at and downgradient of the Sauget Area 1 source areas. The nine indicator constituents include six VOCs (benzene, chlorobenzene, tetrachloroethene, trichloroethene, 1,2-DCE, vinyl chloride), two SVOCs (1,4-dichlorobenzene and 4-chloroaniline), and the herbicide 2,4-D.

The isoconcentration cross sections for benzene, chlorobenzene, 1,4-dichlorobenzene, and 4-chloroaniline are from the Sauget Area 2 Remedial Investigation Report (URS, 2009). New isoconcentration cross sections were prepared for the other indicator constituents, including tetrachloroethene, trichloroethene, cis-1,2-DCE, vinyl chloride, and 2,4-D.

The nine isoconcentration cross sections that extend from Site I South to the Mississippi River, Figures 5-3 through 5-11, correspond to line B-B' on the cross section location map, Figure 5-2. The nine isoconcentration cross sections that extend from Sites G and H to the River, Figures 5-12 through 5-20, correspond to line C-C' on Figure 5-2.

Figures 5-21 through 5-47 are isoconcentration maps for the SHU, MHU, and DHU for the nine Sauget Area 1 indicator constituents. The exceedance areas in the SHU, MHU, and DHU in the Sauget region that shown on Figures 5-48, 5-49, and 5-50 are based on exceedances of any of 14 of the Sauget Area 2 indicator constituents, which include the nine Sauget Area 1 indicator constituents listed above plus nitrobenzene; 2,4-dichlorophenol; 2,4,6-trichlorophenol; 1,2-dichloroethane; and arsenic.

Tables 5-1 through 5-4 present all groundwater testing results that exceed MCLs (or EPA Regional Screening Levels when MCLs are not available) for the SHU, MHU, DHU, and for samples from residential areas, respectively.

### **5.3.1 Groundwater at and Downgradient of Sites I South and North**

A total of seven groundwater samples were collected in the alluvial aquifer beneath Site I South. Constituents detected in the samples from Site I South included 6 VOCs, 31 SVOCs, 11 pesticides, 2 herbicides, PCBs, dioxin, and metals. Summary statistics (minimum, average, and maximum concentrations) for constituents detected in groundwater beneath Site I South are presented on Table 3-28A.

One groundwater sample was collected in the alluvial aquifer beneath Site I North. Constituents detected in the sample from Site I North included 1 pesticide, 1 herbicide, dioxin, and metals. Summary statistics (minimum, average, and maximum concentrations) for constituents detected in groundwater beneath Site I North are presented on Table 3-28B.

Frequency of detection (FOD) and maximum detected concentrations of the nine indicator constituents in the alluvial aquifer beneath the Site I South source area are summarized below. No indicator constituents were detected in the groundwater sample from Site I North.

Site I South Source Area

<u>Indicator Constituent</u>	<u>FOD</u> (%)	<u>Maximum</u> <u>Concentration</u> (ug/l)
Benzene	50	750
Chlorobenzene	50	3,800
Tetrachloroethene	ND	ND
Trichloroethene	ND	ND
1,2-Dichloroethene	13	160
Vinyl Chloride	ND	ND
1,4-Dichlorobenzene	88	14,000
4-Chloroaniline	25	1,800
2,4-D	ND	ND

Twenty-nine groundwater samples were collected in the alluvial aquifer downgradient of Site I and all of these samples were located downgradient of Site I South. Constituents detected in the samples downgradient of Site I South included 11 VOCs, 36 SVOCs, 16 pesticides, 6 herbicides, PCBs, dioxins, metals, and total cyanide. Summary statistics for constituents detected in groundwater downgradient of Site I South are presented on Table 3-29. Frequency of detection and maximum detected concentrations of the nine indicator constituents in groundwater downgradient of Site I South are summarized below:

Downgradient of Site I South

<u>Indicator Constituent</u>	<u>FOD</u> (%)	<u>Maximum</u> <u>Concentration</u> (ug/l)
Benzene	86	620
Chlorobenzene	97	34,000
Tetrachloroethene	24	83
Trichloroethene	17	180
1,2-Dichloroethene	38	1,400
Vinyl Chloride	38	970
1,4-Dichlorobenzene	90	10,000
4-Chloroaniline	86	4,100
2,4-D	24	10.5

### Chlorobenzene, 1,4-Dichlorobenzene, and Benzene

As shown on Figures 5-4 and 5-5, the highest downgradient chlorobenzene and 1,4-dichlorobenzene concentrations occurred in the MHU and DHU at sampling station AA-I-S1, which is located 100 feet downgradient of Site I South.

MAXIMUM DETECTED CONCENTRATIONS DOWNGRADIENT OF SITE I SOUTH (ug/L)			
CHLOROBENZENE			
Sampling Station	AA-I-S1	AA-I-S2	AA-I-S3
Distance from Source Area	100 ft.	650 ft.	1,200 ft.
Shallow Hydrogeologic Unit	8,700	3,200	ND
Middle Hydrogeologic Unit	20,000	19,000	1,800
Deep Hydrogeologic Unit	34,000	11,000	5,500
1,4-DICHLOROBENZENE			
Shallow Hydrogeologic Unit	4,400	4,200	ND
Middle Hydrogeologic Unit	10,000	4,900	1,500
Deep Hydrogeologic Unit	9,700	5,300	3,200

These comparatively high concentrations of chlorobenzene and 1,4-dichlorobenzene are most likely due to dissolution and downgradient transport of DNAPL trapped in the alluvial aquifer matrix and/or pooled on bedrock beneath Site I South. Following vertical migration of liquid waste and/or leaching of dissolved constituents into the hydrogeologic units below Site I, more constituent migration occurred in the MHU and DHU downgradient of the disposal area because their higher hydraulic conductivities resulted in a significantly higher mass flux. Concentrations of chlorobenzene and 1,4-dichlorobenzene decrease between AA-I-S1 and AA-I-S3, which is approximately 1100 feet west of AA-I-S1.

Figure 5-3 shows the profile of the benzene plume at and downgradient of Site I South. Benzene concentrations in groundwater downgradient of Site I South are significantly lower than chlorobenzene and 1,4-dichlorobenzene concentrations.

MAXIMUM DETECTED CONCENTRATIONS DOWNGRADIENT OF SITE I SOUTH (ug/L)			
BENZENE			
Sampling Station	AA-I-S1	AA-I-S2	AA-I-S3
Distance from Source Area	100 ft.	650 ft.	1,200 ft.
Shallow Hydrogeologic Unit	620	120	<1
Middle Hydrogeologic Unit	190	300	74
Deep Hydrogeologic Unit	140	120	72

As indicated on Figures 5-3, 5-4, 5-5, and 5-21 through 5-29, there are other sources of chlorobenzene, 1,4-dichlorobenzene, and benzene in the region crossgradient and downgradient of Sauget Area 1 that contribute to these plumes.

### Chlorinated Ethenes

The tetrachloroethene and trichloroethene concentrations in groundwater (Figures 5-6, 5-7, and 5-30 through 5-35) at and downgradient of Site I South are discontinuous and relatively dilute.

1,2-DCE and vinyl chloride are daughter products generated during reductive dechlorination of tetrachloroethene and trichloroethene. The plumes of 1,2-DCE (Figures 5-8, 5-36, 5-37, and 5-38) vinyl

chloride (Figures 5-9, 5-39, 5-40, and 5-41) had significantly higher concentrations compared to concentrations of tetrachloroethene and trichloroethene, and this suggests that most of the tetrachloroethene and trichloroethene in the alluvial aquifer has already degraded to 1,2-DCE and vinyl chloride.

MAXIMUM DETECTED CONCENTRATIONS DOWNGRAIENT OF SITE I SOUTH (ug/L)			
1,2-DCE			
Sampling Station	AA-I-S1	AA-I-S2	AA-I-S3
Distance from Source Area	100 ft.	650 ft.	1,200 ft.
Shallow Hydrogeologic Unit	1,200	300	<5
Middle Hydrogeologic Unit	310	160	1,400
Deep Hydrogeologic Unit	<1,000	<120	<250
VINYL CHLORIDE			
Shallow Hydrogeologic Unit	970	240	<10
Middle Hydrogeologic Unit	320	<1000	190
Deep Hydrogeologic Unit	<2,000	<250	130

#### 4-Chloroaniline and 2,4-D

The 4-chloroaniline plume (Figures 5-10, 5-42, 5-43, and 5-44) is present at AA-I-S1 and AA-I-S3. At AA-I-S1, the maximum concentration was 4100 ug/L in a sample from the SHU. At AA-I-S3, the maximum concentration was 170 ug/L in a sample from the MHU. The isoconcentration cross section indicates the presence of a separate plume of 4-chloroaniline associated with sources downgradient of Sauget Area 1.

MAXIMUM DETECTED CONCENTRATIONS DOWNGRAIENT OF SITE I SOUTH (ug/L)			
4-CHLOROANILINE			
Sampling Station	AA-I-S1	AA-I-S2	AA-I-S3
Distance from Source Area	100 ft.	650 ft.	1,200 ft.
Shallow Hydrogeologic Unit	4,100	680	<20
Middle Hydrogeologic Unit	1,700	340	170
Deep Hydrogeologic Unit	18	58	100

The 2,4-D plume (Figures 5-11, 5-45, 5-46, and 5-47) is relatively small and dilute. The only detections of 2,4-D were in the DHU at AA-I-S1, with a maximum concentration of 11 ug/L.

#### 5.3.2 Groundwater at and Downgradient of Sites G and H

Two groundwater samples were collected in the alluvial aquifer beneath the Site G source area. Detected constituents included 11 VOCs, 13 SVOCs, 11 pesticides, 6 herbicides, dioxin, and metals. Nine groundwater samples were collected in the alluvial aquifer beneath the Site H source area. Detected constituents included 12 VOCs, 33 SVOCs, 16 pesticides, 5 herbicides, PCBs, dioxin, metals, and total cyanide. Summary statistics for constituents detected in groundwater beneath the Site G and Site H source areas are presented on Tables 3-27 and 3-28. Frequency of detection and maximum detected concentrations of the nine indicator constituents in groundwater beneath the Site G and Site H source areas are summarized below:

Indicator Constituent	Site G Source Area		Site H Source Area	
	FOD (%)	Maximum Concentration (ug/l)	FOD (%)	Maximum Concentration (ug/l)



Benzene	100	3,700	78	2,250
Chlorobenzene	100	4,300	100	4,350
Tetrachloroethene	50	170	ND	ND
Trichloroethene	100	200	33	49.5
1,2-Dichloroethene	100	190	33	17
Vinyl Chloride	50	41	ND	ND
1,4-Dichlorobenzene	100	850	100	14,000
4-Chloroaniline	100	23,000	67	1,800
2,4-D	50	120	33	180

Thirty groundwater samples were collected in the alluvial aquifer downgradient of the Site G source area. Because of the proximity of Sites G, H, and L, the plume downgradient of Site G potentially receives contributions from these three sites. Detected constituents included a total of 9 VOCs, 19 SVOCs, 6 pesticides, 2 herbicides, PCBs, dioxins, and metals. Summary statistics for constituents detected in groundwater downgradient of Sites G, H, and L are presented on Table 3-30. Frequency of detection and maximum detected concentrations of the nine indicator constituents are summarized below:

Indicator Constituent	Downgradient of Sites G and H	
	FOD (%)	Maximum Concentration (ug/l)
Benzene	7	2.2
Chlorobenzene	70	270
Tetrachloroethene	17	13
Trichloroethene	20	2.5
1,2-Dichloroethene	37	20
Vinyl Chloride	3	7.3
1,4-Dichlorobenzene	33	9.5
4-Chloroaniline	7	14
2,4-D	ND	ND

#### Chlorobenzene, 1,4-Dichlorobenzene, and Benzene

As shown on Figures 5-12, 5-13, 5-14, and 5-21 through 5-29, elevated concentrations of benzene, chlorobenzene and 1,4-dichlorobenzene were detected in groundwater beneath the Site G source area at wells EEG-107 and EE-01. The maximum concentrations of benzene and chlorobenzene were detected at EEG-107, which is screened in the SHU beneath Site G. The concentrations of benzene and chlorobenzene at EEG-107 were 3,300 ug/L and 2,600 ug/L, respectively. The maximum concentration of 1,4-dichlorobenzene, 5,300 ug/L, was detected in a groundwater sample from EE-01, which is screened in the SHU and is located between Site G and Site H.

Where not captured by the GMCS, the chlorobenzene, 1,4-dichlorobenzene, and benzene plumes reach the Mississippi River, as shown on the isoconcentration maps. As indicated on the isoconcentration cross sections and maps, there are source(s) of benzene, chlorobenzene, and 1,4-dichlorobenzene in the region that are crossgradient and downgradient of Sauget Area 1.

### **Chlorinated Ethenes**

The isoconcentration cross sections and maps for the chlorinated ethenes (Figures 5-15 through 5-18 and 5-30 through 5-41) indicate that there are relatively small plumes of tetrachloroethene, trichloroethene, and 1,2-DCE associated with the Site G source area. The maximum concentrations were detected in the groundwater sample from well EEG-107, which is screened in the SHU beneath Site G. The concentrations of tetrachloroethene, trichloroethene, and 1,2-DCE at EEG-107 were 280 ug/L, and 390 ug/L, and 240 ug/L, respectively. There were no detections of tetrachloroethene, trichloroethene, or 1,2-DCE in the groundwater samples from TCMW-5 and TCMW-6, which are the next downgradient wells shown on these cross sections. There were no detections of vinyl chloride at any of the sampling locations shown on the vinyl chloride cross section (Figure 5-18).

### **4-Chloroaniline and 2,4-D**

The maximum concentration of 4-chloroaniline shown on the isoconcentration cross section was 15,000 ug/L at well EEG-107, which is screened in the SHU beneath Site G (Figure 5-19). The 4-chloroaniline plume extends approximately 2900 feet downgradient of Site G, but does not reach the Mississippi River. In the downgradient portion of the plume, the maximum concentrations were found in samples from the DHU. As indicated on Figure 5-19, there are source(s) of 4-chloroaniline in the region downgradient of Sauget Area 1.

The isoconcentration cross section for 2,4-D (Figure 5-20) indicates that there is a relatively small plume of 2,4-D associated with the Site G source area. A concentration of 1,200 ug/L of 2,4-D was detected in the groundwater sample from well EEG-107, which is screened in the SHU beneath Site G, and this is the only detection of 2,4-D on this cross section.

## **5.4 Site Conditions After Completion of Sediment and Creek Bottom Soil Removal Actions**

Solutia remediated Creek Segments B, C, D, E and F by removing 46,000 cubic yards of sediments in 2001-2002 and 12,400 cubic yards of sediments and creek bottom soil in 2005-2006. Excavated sediments and soils were transferred to a RCRA and TSCA-compliant on-site containment cell constructed adjacent to the west bank of Creek Segment B just north of Judith Lane (Figure 1-4). Creek bottom soils represent the natural creek bottom material that was present beneath the sediments.

No sediments remained in Creek Segments B, C, D, E, and F after completion of the sediment removal action in 2001-2002, thereby eliminating any potential adverse ecological impacts associated with sediments that were present prior to that time.

By agreement with USEPA, risk-based concentrations (RBCs) for protection of forage fish in Dead Creek were developed for residual concentrations of known bioaccumulative compounds (Total DDT, Dieldrin, gamma-Chlordane, Total PCBs, Dioxin TEQ and Mercury), and site-specific metals (Copper, Lead and Zinc), and Bis(2-ethylhexyl)phthalate. Following the sediment removal efforts within Creek Segments B, C, D, E and F in 2001-2002, the remaining creek bottom soils were sampled and compared against the RBCs. In areas where the RBCs were exceeded, the creek soils were excavated in 2005-2006 and the soils were transferred to the containment cell.

Creek Segments B, C, D and E are not considered to be habitats conducive to sustainable fish populations because these creek segments are periodically dewatered to control mosquitoes. Creek Segment F and the Borrow Pit Lake are habitats conducive to sustainable fish population. The sediment excavation in Borrow Pit Lake in 2005-2006 and the creek bed soil removal in Creek Segment F in 2005-2006 removed concentrations exceeding the RBCs for protection of forage fish.

Based on completion of these remedial actions for sediment and creek bottom soil, Dead Creek is no longer considered an on-going source area.

## 5.5 Floodplain Soil

As discussed in Section 3.5.2, surface and subsurface soil sampling was conducted at transects adjacent to Dead Creek in both developed and undeveloped areas of its floodplain. The results of the floodplain soil sampling indicate that SVOCs, PCBs, dioxins, and copper were found most often at concentrations below or similar to background concentrations. There was no identifiable relationship between concentrations and distance from Dead Creek, indicating that migration of sediment contaminants to adjoining floodplain soils had not occurred.

## 5.6 Air

### 5.6.1 Source Area Ambient Air

As discussed in Section 3.2.5, upwind and downwind air sampling was performed at Sites G, H, I, and L to evaluate the potential for release and migration of constituents. Transport pathways of potential interest include direct volatilization and potential airborne transport of particulate matter containing constituents. Summary statistics for upwind and downwind samples collected at Sites G, H, I and L are presented in Tables 3-17 to 3-24.

The following table lists the chemicals whose maximum downwind concentration was at least two times higher than the concentration in the upwind sample. The table focuses on chemicals that are considered the most likely to be site-related constituents.

**Chemicals Whose Maximum Downwind Concentration was at Least Two Times the Upwind Concentration**

VOC Constituents	Site G Downwind ug/m3	Site H Downwind ug/m3	Site I Downwind ug/m3	Site L Downwind ug/m3
Acetone	717	24	ND	ND
2-Butanone	16.8	24.7	ND	30.5
Ethylbenzene	13.3	1.82	1.69	ND
Dichloromethane	2420	11	2090	890
4-Methyl-2-pentanone	61.9	ND	ND	ND
Styrene	15.9	ND	ND	ND
Tetrachloroethene	2.92	0.909	ND	ND
Toluene	159	ND	ND	ND
1,1,1 Trichloroethane	ND	6.37	ND	ND
Trichloroethene	ND	3.44	ND	ND
SVOC Constituents	Site G ug/m3	Site H ug/m3	Site I ug/m3	Site L ug/m3
1,2 Dichlorobenzene	ND	ND	0.259	ND
1,4 Dichlorobenzene	ND	<2 x upwind	0.42	0.024
2-Nitroaniline	ND	ND	0.0294	ND

The HHRA included a short-term and chronic screening assessment of 24-hour ambient air sample data collected at Sites G, H, I, and L. This approach and completed evaluation were approved by USEPA in the HHRA Work plan (ENSR, 1999) and the HHRA (ENSR, 2001), respectively. The air samples were not used in the calculation of risks in the HHRA because they were 24-hour air samples collected at a single time point. Downwind air sample concentrations were compared to upwind sample concentrations and to risk-based screening levels based on chronic and subchronic/acute exposure scenarios. USEPA Region 9 Preliminary Remediation Goals (PRGs) (1999), which were current at the time the HHRA was conducted, were used as the risk-based screening levels for chronic exposure.

Further evaluation of potential for exposure to constituents that may be present in ambient air is provided in Section 8.2.1 of this report.

### 5.6.2 Vapor Intrusion

As discussed in Section 4.4, a vapor intrusion investigation that was conducted in 2006 included collection of soil vapor samples from three locations at the Wiese facility, three locations at the Sauget Village Hall, three locations at the Cerro Flow Products control center, and one location at a guard shack at the entrance to the Cerro truck parking area (Figure 4-6). The soil vapor samples that were collected during this work program were submitted for laboratory analysis of VOCs. Results are summarized below:

Maximum Detected Concentrations of VOCs in Soil Vapor Samples at Wiese Property, Cerro, and Sauget Village Hall

Constituent	Wiese Building	Cerro Control Center	Cerro Guard House	Sauget Village Hall
	Maximum Concentration (ppbv)	Maximum Concentration (ppbv)	Maximum Concentration (ppbv)	Maximum Concentration (ppbv)
Acetone	ND	12	15	43
Benzene	13,000	1.1	8.2	7.6
1,3-Butadiene	ND	0.22	2.5	4.3
2-Butanone (MEK)	ND	0.81	2.8	9.9
Butylbenzene	ND	1.7	ND	ND
Carbon disulfide	260	1.1	35	8.9
Carbon Tetrachloride	ND	ND	ND	0.15
Chlorobenzene	70,000	ND	ND	140
Chloroethane	ND	ND	0.28	ND
Chloroform	ND	4.1	ND	ND
Chloromethane	ND	0.27	0.2	0.54
Cumene	ND	ND	ND	1.4
Cyclohexane	760	1.8	16	160
1,2-Dichlorobenzene	8,100	ND	ND	0.61
1,3-Dichlorobenzene	600	ND	ND	1.5
1,4-Dichlorobenzene	6,900	ND	ND	7.5
1,1-Dichloroethane	ND	5.5	1.7	ND
1,1-Dichloroethene	ND	0.26	ND	ND
cis-1,2-Dichloroethene	2,800	25	ND	ND
trans-1,2-Dichloroethene	78	ND	ND	ND
Ethanol	ND	1.7	ND	35
Ethyl Acetate	ND	10	ND	ND
Ethylbenzene	680	0.87	1.3	2.9
4-Ethyltoluene	16	0.3	0.49	2.7
Freon 11	ND	0.27	0.28	0.38
Freon 12	ND	0.57	0.49	0.56
Freon 113	ND	0.18	0.2	0.15

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Heptane	650	2	7.1	18
Hexane	2,200	3.8	25	140
Methylene Chloride	ND	ND	ND	44
Naphthalene	3,200	ND	21	ND
4-Methyl-2-pentanone	ND	0.23	0.61	ND
2-Propanol	ND	1.0	ND	2.8
Propylbenzene	ND	ND	0.14	0.79
Styrene	ND	ND	0.22	0.66
1,1,2,2-Tetrachloroethane	ND	0.036	ND	ND
Tetrachloroethene	5,700	31	0.28	1.6
Toluene	7,200	7.7	8.7	35
1,2,4-Trichlorobenzene	170	ND	ND	ND
1,1,1-Trichloroethane	ND	9.9	3.6	ND
Trichloroethene	1,800	22	0.54	3.7
1,2,4-Trimethylbenzene	ND	0.53	0.85	3.2
1,3,5-Trimethylbenzene	ND	0.24	0.45	1
2,2,4-Trimethylpentane	4,600	ND	ND	ND
Vinyl Chloride	9,400	3	ND	0.51
m,p-Xylene	640	2.4	2	9.7
o-Xylene	210	0.59	0.83	3.3

Data from the vapor intrusion investigation were evaluated in the Vapor Intrusion HHRA (ENSR, 2009).

## **6.0 CONTAMINANT FATE AND TRANSPORT**

### **6.1 Sources and Routes of Contaminant Migration**

#### **6.1.1 Source Areas**

Solutia remediated Dead Creek by removing 46,000 cubic yards of sediments from Segments B, C, D, E and F in 2001-2002 and 12,400 cubic yards of sediments and creek bottom soil in 2005-2006 from Creek Segments B, D, E, F, and Borrow Pit Lake. Excavated sediments and soils were transferred to a RCRA and TSCA-compliant on-site containment cell constructed adjacent to the west bank of Creek Segment B just north of Judith Lane (Figure 1-4).

The remaining contaminant source areas at Sauget Area 1 are the disposal areas at Sites G, H, I South, and L. These disposal areas contain municipal and industrial waste materials, including crushed or partially crushed drums, drum fragments, uncontained soil and liquid wastes, wood, glass, paper, construction debris, and miscellaneous trash. There is residual DNAPL in the aquifer matrix underlying portions of Sites G, H, and I South, and the dissolution of residual DNAPL in the MHU and DHU beneath the Site G, H, and I South source areas represents an on-going source of constituents to downgradient groundwater.

Site I North and Site N are not considered to be contaminant source areas. Site I North contains inert fill materials such as bricks, pieces of concrete, large concrete slabs, rebar, sheet metal, wood, fill soil, and gravel. Site N, which is located on property formerly owned by the H. Hall Construction Company, was primarily used for disposal of construction debris. The waste materials found in Site N included soil, brick, concrete, metal, tires, and wood as well as some crushed drums, including a few that contained a pasty whitish material that could have been painting waste.

#### **6.1.2 Routes of Contaminant Migration**

Based on the nature and extent of the source areas at Sauget Area 1, the potential routes of contaminant migration include the following: i) leaching of source materials to groundwater, ii) groundwater transport and discharge to the Mississippi River and the GMCS, iii) volatilization of source materials to ambient air or to indoor air where buildings are present, and iv) erosion and release of source materials. The following paragraphs discuss these four potential routes of contaminant migration.

##### **6.1.2.1 Leaching to Groundwater**

The potential for the source material at the Sauget Area 1 sites to leach to groundwater is based on the leachability of the source material, the age of the source material, the relative amount of leaching that has already occurred, and the type of surface cover. The source material observed in the Sauget Area 1 sites includes constituents that are relatively leachable. Due to the nature of the waste materials present in Sites G, H, I, and L, there is most likely some constituent migration from these fill areas into the underlying aquifer. Section 6.2 summarizes results of mass flux calculations for leaching of unsaturated source materials at Site I South and mass flux from groundwater flushing in the alluvial aquifer beneath Site I South and applies the conclusions to Sites G, H, and L.

#### **6.1.2.2 Groundwater Flow and Discharge to the Mississippi River and the GMCS**

The Mississippi River is located approximately one mile downgradient of Sauget Area 1 Sites G, H, I, and L. In 2003-2004 a Groundwater Migration Control System (GMCS) was installed at Sauget Area 2 Site R, approximately 300 feet from the River and downgradient of Sauget Area 1 sites G, H, I, and L. The GMCS includes a 3,300 ft long, "U"-shaped, fully penetrating barrier wall located downgradient of Site R and three groundwater extraction wells on the upgradient side of the barrier wall.

Groundwater flow to the Mississippi River and the performance of the GMCS have been extensively studied and modeled, and there is evidence that natural attenuation processes remove a significant portion of the mass flux from the Sauget Area 1 plumes before they reach the GMCS and the River. These topics are covered in Sections 6.3, 6.4, and 6.5 of this report.

#### **6.1.2.3 Volatilization**

Volatile constituents present in the subsurface may potentially volatilize to ambient air or, where buildings are present, to the indoor air of overlying buildings (i.e., vapor intrusion). The potential for constituents to volatilize from soil or groundwater to ambient air is dependent on the physical and chemical properties of the constituents, the soil characteristics, and the depth of the constituents.

VOCs have been detected in soil, waste, and/or groundwater samples collected at Sites G, H, I South, and L, and there is potential for those constituents to migrate to ambient air. This potential pathway is evaluated in the Human Health Risk Assessment, which is summarized in Section 8 of this report.

The Wiese building is located at Site G, and there are several occupied buildings at or near Site I South, including the Sauget Village Hall adjacent to Site I South, the Cerro Guard House at Site I, and the Cerro Control Center west of Site I South. Soil gas data collected at these locations in 2006 was summarized in Section 4.4 and was evaluated in a technical memorandum referred to as the Vapor Intrusion Human Health Risk Assessment (ENSR, 2008a).

#### **6.1.2.4 Erosion and Release**

The potential for erosion and release of source materials from the Sauget Area 1 fill areas is limited because the Sauget Area 1 fill areas are protected by the Mississippi River levee system.

### **6.2 Mass Flux from Source Areas Due to Leaching and Lateral Groundwater Flow**

Leachate recovery at Sites G, H, I South, and L is a component in remedial alternative arrays for Sauget Area 1. However, USEPA has acknowledged that leachate recovery is largely an issue related to satisfying State ARARs and may not reduce the time to meet remedial goals.

GSI performed mass flux calculations to estimate mass flux of chlorobenzene, 1,4-dichlorobenzene, and benzene due to: i) groundwater flushing in the alluvial aquifer beneath Site I; ii) leaching of unsaturated Site I South source zone materials prior to installation of a low permeability cover; and iii) leaching of unsaturated Site I South source zone materials after installation of a low permeability cover. A technical

memo, "Mass Flux Estimates, Sauget Area 1" (GSI, 2005) was prepared to document calculation procedures, input parameters, and results. This section summarizes the results of the source area mass flux calculations.

### 6.2.1 Background Information

The calculations were performed for Site I, which has the largest surface area of the four sites and generally has the highest concentrations of COCs. Therefore, the findings of this evaluation for Site I are considered applicable to Sites G, H, and L.

The northern portion of Site I, now known as Site I North, was used primarily for disposal of wastes such as broken concrete, bricks, and other construction debris. Test trenches and borings confirm the presence of construction wastes and fill soils at Site I North. Based on waste characterization data and analytical data from the DNAPL study (GSI, 2005), VOC and SVOC concentrations are significantly lower in fill samples collected from Site I North compared to waste samples collected from Site I South.

The source area is an important variable in the calculation of mass flux of COCs due to leaching of unsaturated source materials. In the mass flux evaluation that was performed in 2005 (GSI, 2005), the mass flux calculations for leaching were performed using the following three alternate assumptions for source area:

- Case 1: Area of residual DNAPL (6.43 acres, see Figure 6-43)
- Case 2: Southern area of Site I interpreted from 1964 air photo (9.47 acres)
- Case 3: Entire area of Site I (19 acres)

Note that the surface areas for Case 2 and Case 3 that were used in the EPA-approved 2005 mass flux evaluation report were overly conservative based on the current understanding of fill boundaries at Site I. Site I South has an area of 8.79 acres, which is approximately 7% lower than the area of 9.47 acres that was used for Case 2 in the 2005 report. Site I North has an area of 5.87 acres, and the entire area of Site I is approximately 14.66 acres, which is approximately 23% lower than the area of 19 acres that was used for Case 3 in the 2005 report. Therefore, the mass flux of COCs due to leaching from unsaturated source materials using the updated areas for Case 2 and Case 3 would be approximately 7% and 23% lower, respectively, than the corresponding values in the 2005 report. However, this does not affect the overall results of the 2005 report because the mass flux of COCs from the unsaturated source materials is very small compared to the mass flux of COCs due to lateral flow in the alluvial aquifer.

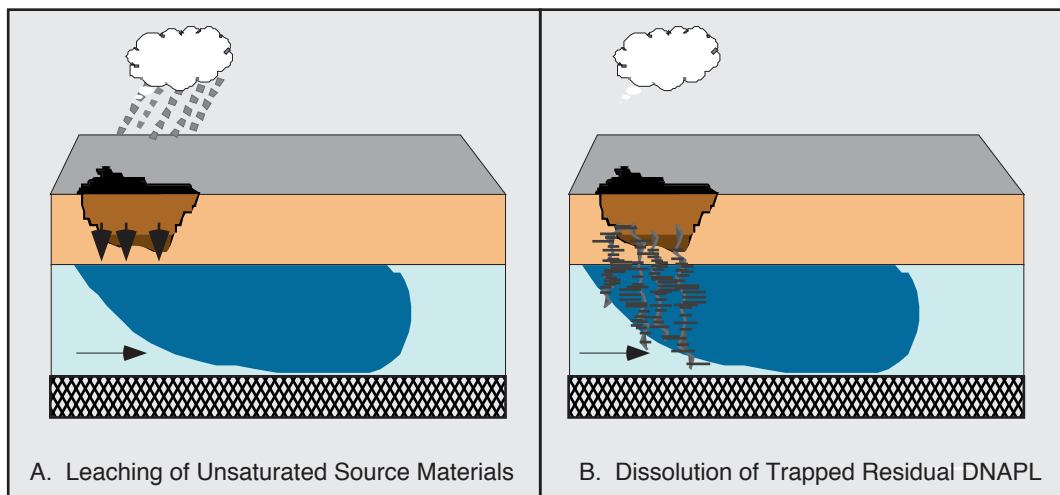
Chlorobenzene and 1,4-dichlorobenzene were initially selected for the mass flux evaluation based on the presence of elevated concentrations of these COCs in groundwater to the west (i.e., downgradient) of Site I and elevated concentrations in Toxicity Characteristic Leaching Procedure (TCLP) samples collected from unsaturated source materials. Benzene was later added to the mass flux evaluation based on USEPA comments to a draft version of the mass flux tech memo. Benzene was the only other COC detected in groundwater downgradient of Site I that was also detected in the TCLP samples collected from the source materials.



The mass flux calculations were performed for two VOCs (chlorobenzene and benzene) and one SVOC (1,4-dichlorobenzene) that are found in Sauget Area 1 waste materials, are prevalent in groundwater underlying Sauget Area 1, and are considered relatively mobile in groundwater. Since the findings of the mass flux evaluation apply to major COCs that are relatively mobile in groundwater, they should also apply to other COCs that are present at Sauget Area 1.

### 6.2.2 Source Release Mechanisms

Knowledge of which source mechanisms are active at a site is important for developing an accurate conceptual model of constituent fate and transport, and for developing appropriate remedial responses. Two source mechanisms that have the potential to be active at Sauget Area 1 are leaching of unsaturated source materials and residual DNAPL dissolution in the alluvial aquifer resulting in mass flux of COCs through lateral groundwater flow.



Two Potential Groundwater Source Mechanisms

Leaching of unsaturated source materials (see Panel A above) results from infiltration of rainfall through near-surface waste materials and contaminated unsaturated soils. Residual DNAPL dissolution (see Panel B above) occurs when soluble organic constituents dissolve from trapped residual DNAPL fingers and pools that entered the subsurface when the source area was active.

Mass flux of COCs in groundwater flowing beneath the unsaturated source materials can be calculated from COC concentration data for the groundwater downgradient of the source materials and groundwater flow rates determined using Darcy's Law and aquifer parameters. These calculations are summarized below and are discussed in more detail in Section 5.0 of the Mass Flux Estimates tech memo (GSI, 2005).

Mass flux of COCs due to leaching of unsaturated source materials can be calculated using TCLP data from waste samples collected in the source materials, predicted rates of leachate generation determined

by the Hydrologic Evaluation of Landfill Performance (HELP) model, and the estimated surface area of the source materials. These calculations are summarized below in Section 6.2.1.4 and are discussed in more detail in Section 6.0 of the Mass Flux Estimates tech memo (GSI, 2005).

### 6.2.3 Mass Discharge Rate Due to Lateral Groundwater Flow

The mass flux of COCs due to lateral groundwater flow is calculated by multiplying the estimated groundwater flowrate through the DNAPL source zone by the COC concentrations in groundwater immediately downgradient of the DNAPL source zone.

The groundwater flowrate is calculated from Darcy's Law, which describes the rate of movement of water through a porous medium, and can be expressed in general terms as follows:

$$\text{Flowrate} = (\text{Hydraulic conductivity}) \times (\text{Hydraulic gradient}) \times (\text{Cross sectional area of flow})$$

The cross sectional area of flow is determined by multiplying the thickness of the water-bearing unit, as determined from borings, and the width of a specified flow area, as measured perpendicular to the groundwater flow direction. For these calculations, the area of interest is the DNAPL source zone within the water-bearing unit, so the width term is referred to as the source width.

Aquifer Thickness: The hydrogeologic conceptual model divides the unconsolidated water-bearing unit into three hydrogeologic units (shallow, middle, and deep). The SHU is generally 0-30 ft below grade, the MHU is generally 30-70 ft below grade, and the DHU is generally 70-110 ft below grade. Depth to water is typically about 15 ft, which means that only the lower 15 ft of the SHU is saturated. Therefore, the assumed saturated thicknesses for the SHU, MHU, and DHU are 15 ft, 40 ft, and 40 ft, respectively.

Hydraulic Conductivity: Separate hydraulic conductivity estimates were developed for the SHU, MHU, and DHU. Estimates of hydraulic conductivity are available from: 1) literature reports (Ritchey and Schicht, 1982), and 2) preliminary analysis of RI/FS slug test data. As requested by USEPA, the site-specific hydraulic conductivity values calculated from the Site I slug tests were used in the mass flux calculations.

Hydraulic Conductivity Values from Slug Test Results at Site I Wells

<u>Hydrogeologic Unit</u>	<u>Site I Well</u>	<u>Hydraulic Conductivity</u> (cm/sec)
SHU	ST-I-S	$4.5 \times 10^{-3}$
MHU	ST-I-M	$5.1 \times 10^{-2}$
DHU	ST-I-D	$1.3 \times 10^{-1}$

Hydraulic Gradient: Based on review of potentiometric surface maps, the hydraulic gradients selected for use in the mass flux calculations for the SHU, MHU, and DHU were 0.001 ft/ft, 0.001 ft/ft, and 0.001 ft/ft, respectively.

Source Widths: Source widths at Site I for the SHU, MHU, and DHU were based on DNAPL areas at Site I identified by the DNAPL Characterization and Remediation Study (GSI, 2005). The Site I source widths are 800 ft for the SHU, 700 ft for the MHU, and 700 ft for the DHU, as shown on Figures 6-44 and 6-45.

Groundwater Flow Rates: Groundwater flow rates through the SHU, MHU, and DHU source zones were obtained using Darcy's Law and the values for hydraulic conductivity, hydraulic gradient, aquifer thickness, and source width as discussed above. The calculated groundwater flux values for the SHU, MHU, and DHU were 0.8 gpm, 21.0 gpm, and 53.6 gpm, respectively.

Groundwater Concentrations Downgradient of Site I: Average chlorobenzene, 1,4-dichlorobenzene, and benzene concentrations in the SHU, MHU, and DHU immediately downgradient of Site I were determined based on average concentrations in groundwater samples from the 0-30 ft, 30-70 ft, and 70-110 ft intervals, respectively, at groundwater sampling location AA-I-S1.

<u>Average Concentrations in Groundwater at AA-I-S1 Downgradient of Site I</u>			
<u>Hydrogeologic Unit</u>	<u>Chlorobenzene (mg/L)</u>	<u>1,4-Dichlorobenzene (mg/L)</u>	<u>Benzene (mg/L)</u>
SHU	5.2	2.2	0.46
MHU	12.3	7.7	0.081
DHU	11.5	6.6	0.088

To estimate mass flux due to lateral groundwater flow beneath Site I, average concentration in groundwater immediately downgradient of Site I was multiplied by groundwater flow rate through the source zone. The mass flux calculations assumed uniform source concentrations in the SHU, the MHU, and the DHU throughout the Site I source zone.

<u>Mass Flux of Three Key Constituents Due to Lateral Groundwater Flow Beneath Site I</u>			
<u>Hydrogeologic Unit</u>	<u>Chlorobenzene (kg/yr)</u>	<u>1,4-Dichlorobenzene (kg/yr)</u>	<u>Benzene (kg/yr)</u>
SHU	8.2	3.5	0.7
MHU	515	322	3.4
DHU	1226	704	9.4

The mass flux values for chlorobenzene, 1,4-dichlorobenzene, and benzene in the SHU, MHU, and DHU are shown on Figures 6-46 and 6-47. Chlorobenzene and 1,4-dichlorobenzene have significantly higher estimated mass flux rates in groundwater than benzene, especially in the MHU and DHU.

Most of the mass flux is in the MHU and DHU. The total mass flux in the MHU and DHU for chlorobenzene, 1,4-dichlorobenzene, and benzene is **2,780 kg/year**.

#### 6.2.4 Estimated Rate of Mass Flux by Leaching at Site I

The equation used for calculating mass flux of each COC due to leaching of unsaturated source materials can be expressed as follows:

$$\text{Mass Flux} = (\text{Leachate concentration}) \times (\text{Percolation rate}) \times (\text{Surface area of source materials})$$

Leachate concentration (in units of mg/L) for each COC was based on laboratory results of TCLP analyses of four waste samples collected in 1999 from the Site I source materials. As documented in Section 6.2 of the Mass Flux Tech Memo (GSI, 2005), the median concentrations for chlorobenzene, benzene, and 1,4-dichlorobenzene in the TCLP leachate were 1.2 mg/L, 0.14 mg/L, and 1.1 mg/L, respectively.

Estimated percolation rates, or leachate generation rates (in units of inches/year), were determined using the Hydrologic Evaluation of Landfill Performance (HELP) model. The HELP model was used to predict the percolation rates at Site I under two scenarios: i) existing conditions; and ii) after installation of a low permeability cover. As documented in Attachment 5 of the Mass Flux Tech Memo (GSI, 2005), output from the HELP model indicates that average annual percolation through the unsaturated waste and fill materials at Site I is approximately 7.3 inches/year under existing conditions. After the low permeability cover is installed, average annual leakage through the bottom layer of the low permeability cover is estimated at approximately  $8 \times 10^{-2}$  inches/year.

The surface area in the above equation refers to the surface footprint of the waste materials at Site I. The total area of Site I is approximately 19 acres, but it has been reported that the northern portion of Site I was used primarily for disposal of construction wastes. It is possible that the mass flux of COCs leached from the fill/waste materials in the northern portion of Site I is small compared to the mass flux of COCs from the southern portion of Site I. Therefore, the mass flux calculations were performed using three alternate values for source area.

- Case 1: Area of residual DNAPL from Figure 1 in DNAPL Report (6.43 acres, see Figure 6-23)
- Case 2: Southern area of Site I interpreted from 1964 air photo (9.47 acres)
- Case 3: Entire area of Site I (19 acres).

Using the equation presented above and the three alternate values for the Site I source area, calculated mass flux from leaching of unsaturated source materials was as follows:

<b>Mass Flux of Key Constituents from Leaching of Source Materials at Site I Assuming 6.43-Acre Source Area</b>			
<b>Scenario</b>	<b>Chlorobenzene (kg/yr)</b>	<b>1,4-Dichlorobenzene (kg/yr)</b>	<b>Benzene (kg/yr)</b>
<b>Existing Conditions</b>	<b>5.8</b>	<b>5.3</b>	<b>0.7</b>
<b>Low-K Cover</b>	<b>0.007</b>	<b>0.006</b>	<b>0.001</b>

<b>Mass Flux of Key Constituents from Leaching of Source Materials at Site I Assuming 9.47-Acre Source Area</b>			
<b>Scenario</b>	<b>Chlorobenzene (kg/yr)</b>	<b>1,4-Dichlorobenzene (kg/yr)</b>	<b>Benzene (kg/yr)</b>
<b>Existing Conditions</b>	<b>9</b>	<b>8</b>	<b>1.0</b>
<b>Low-K Cover</b>	<b>0.01</b>	<b>0.01</b>	<b>0.001</b>

<b>Mass Flux of Key Constituents from Leaching of Source Materials at Site I Assuming 19-Acre Source Area</b>			
<b>Scenario</b>	<b>Chlorobenzene (kg/yr)</b>	<b>1,4-Dichlorobenzene (kg/yr)</b>	<b>Benzene (kg/yr)</b>
<b>Existing Conditions</b>	<b>17</b>	<b>16</b>	<b>2.0</b>
<b>Low-K Cover</b>	<b>0.02</b>	<b>0.02</b>	<b>0.002</b>

Without a low permeability cover, estimated mass flux values for chlorobenzene, 1,4-dichlorobenzene, and benzene due to leaching of unsaturated source materials at the Site I source zone are 17 kg/yr, 16 kg/yr, and 2 kg/yr, respectively (see Figure 6-26), assuming a source area of 19 acres.

After installation of a low permeability cover, mass flux values for chlorobenzene, 1,4-dichlorobenzene, and benzene due to leaching decrease significantly, and are estimated to be 0.02 kg/yr, 0.02 kg/yr, and 0.002 kg/yr, respectively (see Figure 6-27), again assuming a 19 acre source area.

As noted in Section 6.2.1, the surface areas for Case 2 and Case 3 that were used in the EPA-approved 2005 mass flux evaluation report were overly conservative based on the current understanding of fill boundaries at Site I. The mass flux of COCs due to leaching from unsaturated source materials using the updated areas for Case 2 and Case 3 would be approximately 7% and 23% lower, respectively, than the corresponding values in the 2005 report. However, this does not affect the overall results of the 2005 report because the mass flux of COCs from the unsaturated source materials is very small compared to the mass flux of COCs due to lateral flow in the alluvial aquifer.

### **6.2.5 Comparison of Mass Flux Estimates Due to Leaching and Lateral Groundwater Flow**

As summarized on Figures 6-26 and 6-27, estimated mass flux of chlorobenzene, 1,4-dichlorobenzene, and benzene from leaching of unsaturated Site I source materials is small compared to estimated mass flux of these three COCs by lateral groundwater flow in the alluvial aquifer underlying Site I. Mass flux ratios were calculated by dividing the mass flux due to leaching from unsaturated source materials by the mass flux due to lateral groundwater flow through the MHU and DHU.

These results indicate that interior leachate recovery would remove only a relatively small mass of chlorobenzene, 1,4-dichlorobenzene, and benzene at Site I and therefore would not significantly reduce the time to meet remedial goals.

## **6.3 Biodegradation of the Indicator Constituents in Groundwater**

### **6.3.1 Natural Attenuation Processes**

The fate and transport of an organic compound in groundwater is controlled by the compound's physical and chemical properties and the physical, chemical, and biological nature of the subsurface media through which the compound migrates. Several processes are known to cause a reduction in the concentration and/or mass of organic compounds dissolved in groundwater. Those processes that result in a change in a constituent's aqueous-phase concentration but not of the total mass in the system are termed nondestructive. Those processes that result in the reduction of constituent mass are referred to as destructive. Nondestructive processes include advection, hydrodynamic dispersion (mechanical dispersion and diffusion), sorption, dilution, and volatilization. Destructive processes include biodegradation and hydrolysis. Key processes active at Sauget Area 1 are advection, dispersion, sorption, and biodegradation. These four processes are discussed in more detail below.

**Advection** - Advection refers to the transport of solutes by the bulk movement of groundwater. Advection is the most important process driving the downgradient migration of aqueous-phase constituents in

groundwater. The rate at which advective transport influences dissolved phase constituent migration is referred to as the seepage velocity. Seepage velocity is a key parameter in natural attenuation studies because it can be used to estimate constituent travel time.

**Dispersion** - Hydrodynamic dispersion is the process whereby a groundwater plume spreads out from the primary direction of groundwater flow. Dispersion results in reduced constituent concentrations as a result of mixing with groundwater cross gradient and downgradient of groundwater flow. Dispersion occurs as a result of two processes: mechanical dispersion and molecular diffusion. Mechanical dispersion is the dominant dispersion process at typical groundwater velocities. At very low groundwater velocities, molecular diffusion may become the dominant dispersion process. Molecular diffusion is generally ignored for most natural attenuation studies.

Dispersion is a function of groundwater seepage velocity and dispersivity occurs in the longitudinal, transverse, and vertical directions relative to groundwater flow. For most organic compounds, the amount of attenuation provided by dispersion is generally low compared to other attenuation processes such as sorption, biodegradation, and hydrolysis. The amount of attenuation resulting from dispersion is typically estimated using computer models such as BIOCHLOR (Aziz et al., 1999).

**Sorption** - Sorption is a non-destructive process in which organic compounds partition from groundwater and sorb to the aquifer matrix. Sorption of dissolved constituents onto the aquifer matrix results in slowing, or retardation, of the constituent relative to the groundwater seepage velocity and a reduction of aqueous phase concentrations.

The effect of sorption on the transport of organic compounds is represented by the retardation factor. The retardation factor quantifies two processes: 1) the degree to which a particular compound moves slower than the groundwater seepage velocity, and 2) the ratio of total constituent mass per volume of aquifer matrix to the volume of dissolved constituents. As shown in the following table, several of the indicator constituents for Sauget Area 1 have significant retardation factors.

<u>Constituent</u>	<u>Soil-Water Distribution Coefficient, <math>K_d</math></u> (L/kg)	<u>Retardation Factor, R</u> (unitless)
Chlorobenzene	$3.5 \times 10^{-1}$	3.0
1,4-Dichlorobenzene	$9.9 \times 10^{-1}$	6.6
Benzene	$9.4 \times 10^{-2}$	1.5
Tetrachloroethene	$2.5 \times 10^{-1}$	2.4
Trichloroethene	$2.7 \times 10^{-1}$	2.5
cis-1,2-DCE	$5.7 \times 10^{-2}$	1.3
Vinyl Chloride	$3.0 \times 10^{-2}$	1.2
4-Chloroaniline	$1.1 \times 10^{-1}$	1.6
2,4-D	$7.2 \times 10^{-1}$	5.1

**Notes:**

1. Retardation factor,  $R = 1 + (\text{bulk density} \times K_{oc} \times f_{oc} / \text{porosity})$
2.  $K_{oc}$  values for each constituent taken from TACO standard (35 IAC 742, Appendix C)
3.  $f_{oc} = 0.0016$  based on (URS, 2004)

4. Bulk density = 1.7 g/mL and porosity = 0.3 based on typical values

**Biodegradation** - Biodegradation is a microbial-mediated destructive attenuation process. Transformation of an organic compound proceeds via one of two biochemical reaction pathways: 1) use of the compound as a primary growth substrate (i.e., electron donor or electron acceptor) or 2) co-metabolism. The use of the organic constituent as a primary growth substrate is the dominant mechanism resulting in degradation of constituents and occurs when microorganisms gain energy for growth by transferring electrons from an electron donor to an electron acceptor. Co-metabolism is typically less important under naturally occurring conditions (Wiedemeier et al., 1999) as co-metabolic biodegradation rates are much lower than growth-promoting pathways.

Depending on the geochemical characteristics of the hydrogeologic unit, organic compounds can either serve as the electron donor or the electron acceptor in microbial metabolism. Growth-promoting biological oxidation of organic compounds occurs when the microorganism uses the compound as an electron donor in a coupled oxidation-reduction reaction. Biological oxidation may occur under both aerobic and anaerobic conditions. Many organic compounds can be used as electron donors in microbial metabolism, including petroleum-related hydrocarbons (e.g., BTEX), and the less oxidized chlorinated compounds such as dichloroethene (DCE), vinyl chloride, chlorobenzene, and the dichlorobenzene isomers. The most preferable electron acceptor utilized during biological oxidation of organic compounds is oxygen. Use of oxygen as an electron acceptor results in high energy yield for the microorganism; therefore, oxidation of organic compounds occurs relatively quickly in aerobic environments. Once oxygen has been depleted by aerobic bacteria, anaerobic consortia utilize alternate electron acceptors (e.g., nitrate, Fe(III), sulfate, carbon dioxide) during the oxidation of organic compounds.

Growth-promoting biological reduction of chlorinated organic compounds occurs when microorganisms utilize the chlorinated constituent as an electron acceptor during reductive dechlorination (or halorespiration). Reductive dechlorination occurs only under anaerobic conditions. The key electron donor in the reductive dechlorination process is hydrogen, which is produced during the fermentation of organic substrates, such as naturally occurring organic matter or co-contaminants such as BTEX.

### 6.3.2 Biodegradation of Chlorobenzenes

Chlorobenzenes can be degraded by a variety of both aerobic and anaerobic bacteria. Biodegradation generally proceeds faster aerobically (Wenderoth et al. 2003), and oxygen availability is a common rate-limiting factor for microbial-mediated chlorobenzene transformation.

**Aerobic Biodegradation of Chlorobenzenes** – Chlorobenzene and the DCB isomers, have been shown to be biodegradable under aerobic conditions. Several studies have shown that aerobic microorganisms utilize chlorobenzene (Reineke and Knackmuss, 1988; van der Meer et al., 1998; Rittman and McCarty, 2001) and the DCB isomers (Reineke and Knackmuss, 1988; van der Meer, 1991; Nielsen and Christensen, 1994; Rittman and McCarty, 2001) as growth-promoting substrates. These and other studies have further indicated the microorganisms capable of carrying out such degradation reactions are commonly encountered at contaminated sites.

The pathway for aerobic biodegradation of chlorobenzene is similar to that observed for BTEX degradation (van der Meer et al., 1998), and results in complete mineralization of chlorobenzene to chloride, carbon dioxide, and water. A similar pathway for the aerobic biodegradation of the DCB isomers has been proposed by van der Meer et al. (1991). Due to complete mineralization, the aerobic biodegradation of chlorobenzenes does not result in the production or accumulation of "daughter" products.

**Anaerobic Biodegradation of Chlorobenzenes** - Several reports have documented the anaerobic biodegradation of chlorobenzenes (e.g., Sims et al., 1991; Middeldorp et al., 1997; Heidrich et al., 2004; Kaschl et al., 2005). There are two energy-yielding processes by which chlorinated compounds undergo anaerobic biodegradation: 1) reductive dechlorination and 2) direct oxidation (Wiedemeier et al., 1999). The specific degradation pathway depends on several factors including: i) the number of chlorine atoms on the molecule; ii) the geochemical conditions; and iii) the microbial consortia. In general, the more highly chlorinated compounds are only susceptible to reductive dechlorination, while the less chlorinated compounds are susceptible to both reductive dechlorination and direct anaerobic oxidation (U.S. EPA, 1998).

The reductive dechlorination pathway for chlorobenzenes proceeds via the sequential removal of a chlorine atom from the molecule. Reductive dechlorination of the DCB isomers to chlorobenzene has been well documented through both laboratory experiments (Ramanand et al., 1993; Nowak et al., 1996; Middeldorp et al., 1997) and in-situ field demonstrations (Heidrich et al., 2004). Further reduction of chlorobenzene to benzene has been suggested based on field and laboratory observations (Nowak et al., 1996; Kaschl et al., 2005), but isolation of microorganisms that carry out this reaction has not been documented.

Mineralization of chlorobenzene via direct anaerobic oxidation has also been suggested (Kaschl et al., 2005). This reaction, analogous to the direct anaerobic oxidation of vinyl chloride, likely proceeds via a pathway similar to that observed for anaerobic benzene oxidation. Similar to aerobic oxidation, direct anaerobic oxidation of chlorobenzene results in complete mineralization to chloride, carbon dioxide, and water without the production or accumulation of daughter products.

Anaerobic degradation of chlorobenzene proceeds slowly relative to anaerobic degradation of the DCB isomers. As a result, the chlorobenzene plumes are more persistent than the DCB plumes at the Sauget sites.

**Geochemical Conditions for Biodegradation of Chlorobenzenes** - For the aerobic biodegradation of chlorobenzenes, the most important geochemical condition is the presence of dissolved oxygen. The presence of abundant electron donor, such as within a contaminant plume, often leads to the rapid depletion of dissolved oxygen. Dissolved oxygen is replenished through recharge of groundwater from upgradient of the source, infiltration of rain water, and groundwater mixing at the fringes of the plume.

There are two pathways for the biodegradation of chlorobenzene and DCB isomers under anaerobic conditions: reductive dechlorination and direct oxidation. Reductive dechlorination predominantly occurs under sulfate-reducing or methanogenic conditions, once other electron acceptors (i.e., oxygen, nitrate,



and Fe(III)) have been depleted. Reductive dechlorination has also been observed under nitrate-reducing and iron-reducing conditions, but reaction rates are typically lower. Therefore geochemical conditions indicative of reductive dechlorination include:

- low dissolved oxygen concentrations,
- low nitrate concentrations,
- low sulfate concentrations,
- elevated Fe(II) concentrations,
- elevated methane concentrations, and
- elevated chloride concentrations.

The direct anaerobic oxidation of chlorobenzenes has not been widely studied. However, the process is likely analogous to the anaerobic oxidation of similar contaminants that have been well documented, such as vinyl chloride and BTEX. The anaerobic oxidation of these compounds has been observed under a variety of geochemical conditions including nitrate-reducing, iron-reducing, sulfate-reducing, and methanogenic (Wiedemeier et al., 1999).

### 6.3.3 Biodegradation of Chloroethenes

Chloroethenes include the compounds tetrachloroethene, trichloroethene, cis-1,2-DCE, trans-1,2-DCE, 1,1-dichloroethene (1,1-DCE) and vinyl chloride. Tetrachloroethene, trichloroethene, 1,2-DCE, and vinyl chloride are indicator constituents at Sauget Area 1. In anaerobic environments, the highly chlorinated solvents undergo reductive dechlorination in a process that is thermodynamically favorable because of the relatively high oxidation state of the carbon in these compounds (see reviews in Christ et al., 2005; Löffler and Edwards, 2006). The reaction involves the transfer of electrons to the chlorinated solvent compound coupled with the release of chloride, yielding lesser chlorinated metabolites. Consequently, reductive dechlorination is a stepwise process, with tetrachloroethene dechlorinated to trichloroethene, DCE (primarily the cis-1,2-DCE isomer), vinyl chloride, and finally to ethene. In general, each of these successive reactions occurs at a slower rate than the preceding step in the reaction.

In many cases, the microbes that mediate these reactions can use one or more of the chlorinated solvents as an electron acceptor in an energy-conserving process (halorespiration). In a subsurface setting, reductive dechlorination will occur once more favorable electron acceptors (i.e., oxygen, nitrate, iron/manganese, sulfate) are largely depleted, although reductive dechlorination often proceeds in conjunction with sulfate-reduction and methanogenesis, albeit at a slower rate. Stimulating dechlorination activity requires adequate concentrations of both the electron acceptor (the chlorinated solvent) and electron donor (typically a hydrogen-generating fermentable carbon compound). In some cases, DCE and vinyl chloride can accumulate because reductive dechlorination of these compounds requires more strongly reducing environments (relative to tetrachloroethene and trichloroethene). Alternate reaction pathways, including anaerobic oxidation of DCE and vinyl chloride to carbon dioxide, are known to exist but the contribution of these pathways to attenuation relative to reductive dechlorination is largely unknown.

Highly chlorinated solvents tend to be recalcitrant in aerobic environments because reductive dechlorination is not energetically favorable and dechlorinating microbes are inhibited by oxygen. However, oxidation of lesser chlorinated metabolites, including vinyl chloride and, to a lesser extent, DCE readily occurs as long as there is a co-substrate (e.g., methane, propane) present to stimulate aerobic organisms. Vinyl chloride is also known to serve as a primary substrate (electron donor) for a number of aerobic microbes. Trichloroethene tends to be slowly degraded in aerobic conditions, while tetrachloroethene is not known to oxidize in oxygen-rich groundwater. In all of these oxidation reactions, the end products are carbon dioxide, water, and chloride; organic intermediates formed during these reactions are generally extremely short-lived.

#### **6.3.4 Biodegradation of Benzene**

Benzene can be rapidly mineralized in aerobic conditions by a number of different types of indigenous microbes (Alvarez and Vogel, 1991; Borden et al., 1994). Using data from 26 lab and field studies of aerobic benzene degradation, Rifai and Suarez (1999) determined that the median half-life was approximately 3.5 days. It is generally accepted that this type of microbial metabolic capacity is widespread in nature. Therefore, significant benzene biodegradation activity (i.e., at levels which will affect the size of the plume) typically exists or can be stimulated (i.e., through addition of oxygen and/or nutrients) at a given site. Benzene can serve as a sole carbon and energy source during this oxidation reaction for a variety of organisms, though not all organisms that catalyze the reaction are capable of coupling it to a growth-supporting process. The metabolic strategy involves a succession of attacks by oxygenase enzymes to make the compound more susceptible to ring cleavage. This degradation results in complete mineralization to CO<sub>2</sub> and water, and accumulation of organic intermediates is generally not observed.

Benzene is also biodegradable in anaerobic environments (Bolt et al., 2002; Lovley, 2000; Johnson et al., 2003; Foght, 2008), such as iron-reducing (Anderson et al., 1998), sulfate-reducing (Lovley et al., 1995), nitrate-reducing (Burland and Edwards, 1999), and methanogenic conditions (Weiner and Lovley, 1998). Because depletion of all available oxygen can occur rapidly following a release, the overall contribution of the anaerobic reactions to fuel hydrocarbon degradation is believed to be significant at some sites (Foght, 2008). However, the occurrence of anaerobic benzene degradation appears to be highly site-specific, with lag times prior to the initiation of degradation and/or inhibition when other fuel hydrocarbons are present. In general, reaction rates for anaerobic degradation are lower than those observed for aerobic biodegradation.

Benzene serves the same metabolic function (carbon and energy source) in both aerobic and anaerobic degradation, although different microbial populations are responsible in each case. Pathways for anaerobic biodegradation of benzene are still being elucidated (Foght, 2008), but the mineralization process yields the same products as those generated in aerobic respiration (CO<sub>2</sub>, water, and biomass), along with the reduced species of the electron acceptor.

### 6.3.5 Biodegradation of 4-Chloroaniline

The degradation of 4-chloroaniline under both aerobic and anaerobic conditions has been reported (Bollag and Russel, 1976; Zeyer et al., 1985; Radianingtyas et al., 2003; McLaughlin et al., 2006; Vangnai and Petchkroh, 2007; Tongarun et al., 2008), although the relative reaction rates are not well documented. The majority of studies have focused on aerobic degradation using pure cultures or enrichments from soils where chloroaniline is present. In some cases, 4-chloroaniline has been shown to support growth of microbes that mediate the degradation reactions, while others rely on aniline as a growth substrate during degradation of 4-chloroaniline. Aerobic degradation of 4-chloroaniline has been observed to occur first by oxygenase attack to produce 4-chlorocatechol, followed by a meta-cleavage or modified ortho-cleavage pathway that eventually results in mineralization (i.e., CO<sub>2</sub>). A recent study on reductive dechlorination of chlorinated anilines suggests that anaerobic degradation of 4-chloroaniline is limited (Tas et al., 2007).

### 6.3.6 Biodegradation of 2,4-D

The herbicide 2,4-dichlorophenoxyacetic acid (2,4-D) is readily biodegradable in aerobic conditions (Estrella et al., 1992; Ka et al., 1994). During this degradation process, it can serve as a sole carbon and energy source for a variety of organisms (Ka et al., 1994). While 2,4-D degradation activity appears to be widespread and has been observed in soils with no history of 2,4-D exposure (Kamagata et al., 1997), a lag time has been observed before the onset of degradation, presumably following growth of a suitable microbial population. The degradation pathway generally proceeds through removal of the phenoxy group and possibly one of the chloride ions, followed by oxygenase and hydroxylase mediated reactions to make the compound more susceptible to ring cleavage (Kitagawa et al., 2002). This degradation results in complete mineralization to CO<sub>2</sub>, and accumulation of intermediates has not been widely reported. Anaerobic degradation of 2,4-D has not been extensively studied, but reductive dechlorination to 4-chlorophenol is known to occur in anaerobic conditions (Mikesell and Boyd, 1985), and anaerobic mineralization of this compound is well documented (Haggeblom and Young, 1995).

## 6.4 Regional Groundwater Flow and Contaminant Transport Model

### 6.4.1 Background and Objectives

The southern portion of the American Bottoms aquifer is or has the potential to be affected by constituents originating from several facilities and waste management sites. Although several previous modeling efforts have focused on the American Bottoms aquifer, there was no single integrated flow and fate and transport model that could evaluate all sites of interest on a regional scale.

GSI was retained by URS Corporation to develop a regional groundwater flow and contaminant transport model covering the southern portion of the American Bottoms aquifer. The study area includes the Sauget Area 1 sites, the Sauget Area 2 sites, and the Krummrich facility in and around the Village of Sauget and the Village of Cahokia in St. Clair County, Illinois. Other sites of interest include ConocoPhillips East St. Louis Terminal and Clayton Chemical facility.

The objectives of the modeling project, as stated in the Groundwater Modeling Plan (GSI, 2006a), were to upgrade/enhance the GSI 2001-2005 groundwater model into a regional model encompassing the Sauget/Cahokia areas such that

- 1) the modeled flow paths can be validated using actual plume measurements made during the RI phase;
- 2) a sensitivity analysis can be performed to assess how groundwater flow and contaminant nature and extent respond under various remedial alternatives during the FS phase;
- 3) the capture zone of the Sauget Area 2 GMCS can be further defined; and
- 4) the vertical mass flux of chemicals can be evaluated from both a site-specific and a regional perspective.

In addition, the model can be calibrated to explain constituents at locations identified as locations of concern by the USEPA. Development and calibration of the flow and contaminant transport model are summarized below and are described in more detail in the groundwater model report (GSI, 2008b).

#### **6.4.2 Groundwater Flow Model**

##### **6.4.2.1 Description of Groundwater Flow Model**

The MODFLOW groundwater flow model was developed using data from previous hydrogeologic characterization projects, existing groundwater models (Geraghty and Miller, 1993; Clark, 1997; and GSI, 2002-2005), and new data developed as part of the Sauget Area 1, Sauget Area 2, and Krummrich site investigations.

The model domain measured 8 miles by 8 miles. A non-uniform finite-difference grid with 60 ft by 60 ft cells in the vicinity of the Sauget Area 2 GMCS was used with cell size gradually increasing with distance from Site R. The Mississippi River served as the boundary condition on the western edge of the model. Constant head cells were used in the model to represent the eastern boundary of the model domain (the bluff line). Because flow is primarily east to west, the northern and southern boundaries of the model domain were represented as no-flow boundaries.

The three hydrogeologic units at the site were each represented by a separate layer. The top layer, corresponding to the SHU, was simulated as an unconfined unit. The second layer, corresponding to the MHU, was simulated as a convertible confined/unconfined unit. The bottom layer, representing the DHU, was simulated as a confined unit. Top and bottom elevations of the model layers were based on information from several sources, including USGS topographic data, stratigraphic elevation data from cross sections, and bedrock elevations from previous studies. Initial hydraulic conductivity values for the SHU were based on previous modeling studies and were assumed to be a single value across the model domain. Values of hydraulic conductivity for the MHU and DHU were taken from a detailed analysis of American Bottoms aquifer test data.

An initial surface infiltration rate of 7.8 inches per year was used throughout the entire model domain to represent infiltration from rainfall. This infiltration rate was based on data from the previous modeling studies.

The Mississippi River was modeled using MODFLOW's river package. Each river cell was assigned a river stage, river bottom elevation, and conductance. River stage was based on a gauging station near Site R and was assumed constant for all river cells in the model. River bottom elevations for each cell were based on bathymetric data from U.S. Army Corps of Engineers.

A regional pumping center, assumed to be withdrawing groundwater from all three layers, was established in the model to represent ongoing highway dewatering projects in the East St. Louis area. The Sauget Area 2 GMCS was also incorporated into the model. The GMCS system consists of a "U"-shaped slurry wall (3 ft wide, 3,300 ft long, 140 ft deep) located between Sauget Area 2 Site R and the Mississippi River and three groundwater extraction wells between the slurry wall and Site R.

A total of 126 head observation wells were imported into the model at locations where heads were measured during the July 6-8, 2005 static water level survey for comparison of simulated to measured heads.

Key model attributes, assumptions, input data for the MODFLOW model are listed on Table 6.1 and are described in detail in Section 6 of Part 1 of the modeling report (GSI, 2008).

#### **6.4.2.2 Calibration of Groundwater Flow Model**

The groundwater model was calibrated so that the simulated water levels in the model were representative of several actual potentiometric (water level) maps of data collected in 1962, 1990, and 2005. During calibration, model inputs such as river conductance, boundary conditions, pumping rates from wells, Mississippi River stage, and hydraulic conductivity were adjusted to reduce the difference between measured and simulated groundwater levels.

During the development of the contaminant transport model, changes were made to the groundwater flow model in an attempt to meet the goals stated above in Section 6.1.1.

The final model simulates the regional aquifer system with an overall root mean squared (RMS) error of 0.7 ft and mean residual (MR) error of 0.06 ft for the model calibration to July 2005 water level data. Individual RMS errors of 0.8 ft, 0.6 ft, and 0.6 ft were obtained for the Shallow Hydrogeologic Unit (SHU), Middle Hydrogeologic Unit (MHU), and Deep Hydrogeologic Unit (DHU), respectively. Individual MR errors of 0.1 ft, 0.01 ft, and -0.06 ft were obtained for the SHU, MHU, and DHU, respectively. These RMS error values indicate that, in general, simulated water levels closely match actual water levels.

#### **6.4.3 Groundwater Contaminant Transport Model**

##### **6.4.3.1 Description of Groundwater Contaminant Transport Model**

The American Bottoms Regional Groundwater Contaminant Transport model was developed using data from previous hydrogeologic characterization projects, existing groundwater models, and data developed as part of the Sauget Area 1 sites, Sauget Area 2 sites, and Krummrich facility investigations.

The MT3D mass transport code (Waterloo Hydrogeologic, 2006) was used to evaluate the movement of dissolved chlorobenzene, 1,4-dichlorobenzene, and 2,4-dichlorophenoxyacetic acid (2,4-D) migrating in the groundwater. A first-order biodegradation decay rate for dissolved constituents (i.e., biodegradation of plumes rather than sources) was used to model chlorobenzene, 1,4-dichlorobenzene, and 2,4-D.

The RT3D mass transport code (Clement, 1997), with sequential decay, was used to evaluate the migration and degradation pathways of the dissolved chlorinated solvents tetrachloroethene, trichloroethene, cis-1,2-dichloroethene (1,2-DCE), and vinyl chloride migrating in the groundwater. Visual MODFLOW Premium Version 4.2 was used as the pre- and post- processor and as the user interface to the MT3D/RT3D codes.

Calibration of the fate and transport model was based on chlorobenzene for VOCs, 1,4-dichlorobenzene for SVOCs, 2,4-D for herbicides, and tetrachloroethene, trichloroethene, cis-1,2-dichloroethene, and vinyl chloride for chlorinated solvents.

**Source Areas** - Initial Krummrich source areas were assigned using DNAPL and sorbed concentration maps from the RCRA Corrective Measures Study. Sauget Area 1 source areas were assigned using DNAPL maps from the DNAPL Characterization and Remediation Study. Clayton source areas were assigned based on existing groundwater data and source location and strength. Sauget Area 2 source areas were based on existing well concentrations located in Sites O, P, Q, R, and/or S.

**Source Concentrations and Source Decay** - An Access database was created containing concentration data from 1983 to 2006. Source concentrations over time in the Shallow, Middle, and Deep Hydrogeologic Units were estimated using data on constituent concentrations at specific wells and at specific times. The vertical mass flux of constituents from within the unsaturated zone into the aquifer was incorporated into the model as decaying-concentration source zones in the SHU.

Initially, source concentrations were assumed to be equal to observed average concentrations within a source zone. Historical and future source concentrations were estimated by projecting source concentrations backward and forward in time assuming a conservative first-order source decay half-life of 40 years. Note that this approach for modeling the source strength vs. time *does not* mean that all the sources in the model were assumed to be attenuated within 40 years. Rather, this approach assumed the sources were decaying relatively slowly, with the source concentration falling by 50% every 40 years. Because most of the source zones had high starting concentrations relative to the groundwater protection standards, all these sources persisted in the model for more than 40 years.

**Initial Concentrations** - Sources at the site began potentially in the 1920s. Assuming a general travel time of 10-30 years from sources to discharge points, a model start time of 1950 was selected as a conservative value. During the calibration process, using a starting time of 1960 instead of 1950 decreased the model run time without a significant impact to the calibration statistics. Therefore, all runs after the initial calibration runs had a simulation start time of 1960.

Since Visual MODFLOW does not permit a barrier wall to turn on and off, the initial simulation was run in two segments. The first segment was from 1960 to 2003 and did not include the GMCS. Concentrations

from this segment were then used as starting concentrations for the next segment. The second segment was from 2003 to 2006 and included the GMCS.

Source locations and strengths for this initial period were adjusted until the concentrations predicted by the MT3D/RT3D model were within reasonable agreement with observed concentrations. This 46-year concentration distribution was then used as the initial condition for all subsequent mass transport modeling.

**Biodegradation and Sorption** - Biodegradation kinetics of all dissolved constituents were assumed to be first-order. Initial dissolved-phase biodegradation rates for each COC were obtained from Illinois Tiered Approach to Corrective Action Objectives (TACO) (35 IAC 742) standard. These rates for chlorobenzene were adjusted during calibration so that the predicted concentrations were in reasonable agreement with observed concentrations at the site. The adjusted biodegradation rates used in the model are conservative relative to TACO rates as discussed in detail in the calibration section of the modeling report (GSI, 2008).

Adsorption of organic species was assumed to be linear. Retardation factors for simulating sorption of dissolved constituents to aquifer media were calculated from distribution coefficients calculated using  $K_{oc}$  taken from the TACO standard and assuming a fraction organic carbon ( $f_{oc}$ ) of 0.0016.

**Dispersion** - Initially, a longitudinal dispersivity value of 32 ft was used in the model based on the Xu and Eckstein (1995) equation. A transverse/longitudinal dispersivity ratio of 0.1 and a vertical/longitudinal dispersivity ratio of 0.01 were used in the model.

**Hydraulic Conductivity** - Although varying the horizontal hydraulic conductivity was evaluated during the calibration of the contaminant transport model, it did not result in an improved calibration. Therefore, the horizontal and vertical hydraulic conductivities in the final model remained unchanged from the flow model.

**Concentration Observation Wells** - Concentration observation wells for each COC were imported into the model at locations where concentrations were measured during the 2005-2006 Supplemental Investigation for comparison of simulated to measured concentrations. For some constituents (such as the chlorinated ethenes), the observed plumes were relatively small and had only a few wells with detectable values.

#### 6.4.3.2 Calibration of Groundwater Contaminant Transport Model

As discussed in the groundwater model report (GSI, 2008b), the model was calibrated so that groundwater concentrations simulated in the model were representative of measured groundwater concentrations observed in 2005 and 2006. During calibration, model inputs such as source concentrations, biodegradation rates, dispersion, recharge, pumping rates from certain identified wells, and horizontal hydraulic conductivity were adjusted to reduce the difference between simulated and observed concentration levels. The calibration resulted in a conservative model that may overpredict the impacts of some site constituents.

Two fate and transport models (RT3D for chlorinated solvents and MT3D for all other constituents) were used to simulate the movement of groundwater plumes from the source zones in the model domain. Simulations started in the 1950 to 1960 time period and were adjusted (calibrated) to match observed groundwater plumes in 2005/2006. The models were then used to simulate potential plume status up to the year 2038.

The following steps were included in the development and calibration of the fate and transport model:

- 1) Using the calibrated flow model to account for groundwater flow conditions for the periods of interest;
- 2) Using chlorobenzene as key constituent to develop the model due to the breadth and detailed coverage of the chlorobenzene database;
- 3) Compiling source data to determine size, strength, and temporal patterns in source concentrations;
- 4) Entering source concentration vs. time data in the fate and transport model;
- 5) Building a database of observed concentration data for the calibration period (2005/2006);
- 6) Running the entire model (flow model + fate and transport model) from 1950 to 2003 (period when the GMCS was not active);
- 7) Taking the resulting 2003 plume concentrations and entering these concentrations in a new model for the 2003 to 2005/2006 timeframe (period when the GMCS was active);
- 8) Comparing the modeled concentrations to observed concentrations;
- 9) Changing the model parameters in an attempt to improve the match; and
- 10) Repeating steps 3-9 for other constituents of concern: 1,4-dichlorobenzene, 2,4-D, tetrachloroethene, trichloroethene, cis-1,2-dichloroethene, and vinyl chloride.

In 2011 IEPA provided updated pumping rates for the on-going highway dewatering projects located in the East St. Louis area (IEPA, 2011). Based on the IEPA memorandum, the 2008 regional groundwater flow and transport model was updated in 2012 to include certain revisions to the historical pumping rates. In addition, the highway dewatering system was assumed to stay on for the duration of the modeling (i.e., through 2038) rather than terminating in 2010, as simulated in the 2008 groundwater model. The updated model was used to determine the percent of dissolved constituent mass flux captured by the Sauget Area 2 GMCS (GSI, 2012).

Section 6.4.3.3 describes results of the calibration of the groundwater contaminant transport model as documented in the original groundwater model report (GSI, 2008b). Section 6.4.3.4 describes results of the 2012 update of the model (GSI, 2012). Section 6.4.3.5 discusses modeled isoconcentration contour maps for the seven Sauget Area 1 indicator constituents.

#### **6.4.3.3 Key Results from Calibration of Groundwater Contaminant Transport Model (GSI, 2008b)**

The 2008 groundwater model report (GSI, 2008b) provides detailed discussion of calibration results. Key results from the calibration efforts are summarized below:



- Historical industrial and highway dewatering activities have had significant effects on the distribution of the observed contaminant plumes today;
- Due to a lack of detailed flow records for industrial and highway dewatering wells, it is impossible to match the current observed plumes precisely. Nevertheless, a model that generally matched the key features of the groundwater plumes was constructed. This model can be used to meet the objectives presented earlier.
- Calibration efforts focused on evaluating the model response to a number of variables, including dispersivity (related to groundwater mixing), biodegradation rates, source decay rates, infiltration, industrial pumping well location and pumping rates, and highway dewatering well flowrates over time. After evaluating these parameters, a “Base Case” was developed that represented the best match that was achieved by manipulation of model variables.
- Key features of the existing chlorobenzene plume were matched with the model. These features included i) higher observed concentrations associated with the Krummrich, Sauget Area 1, and Sauget Area 2 source zones and sources associated with Clayton Chemical; ii) a portion of the Deep Hydrogeologic Unit (DHU) chlorobenzene dissolved plume extending to the northern portion of Site P, north of the main source zone; and iii) the Site R plume and portions of other plumes being captured by the GMCS.
- When all modeled constituents were included, over 94% of the total plume mass flux (mass discharge rate) is predicted to be captured by the GMCS. The total plume mass flux refers to the combined mass flux from all Sauget source areas, including the Sauget Area 1 sites, the Sauget Area 2 sites, the Krummrich facility, and Clayton. There is considerable variation in the capture efficiency for each constituent. For example:
  - Approximately 99% of the total 2,4-D mass flux (~11,000 kilograms per year) is predicted to be captured by the GMCS in 2038.
  - Approximately 91% of the vinyl chloride is predicted to be captured by the GMCS in 2038.
  - Approximately 88% of the chlorobenzene mass flux is predicted to be captured by the GMCS in 2038.
  - Although only 48% of the trichloroethene mass flux is predicted to be captured by the GMCS in 2038, this is a comparatively small plume compared to the mass flux of the other constituents (total mass flux of 17 kilograms per year of trichloroethene going to the river or the GMCS compared to ~21,000 kilograms per year for all seven constituents).

When the highway dewatering system in East St. Louis is shut down as planned in 2010 (as assumed in the 2008 groundwater model), groundwater flow from the aquifer to the river will increase, increasing the overall mass flux to the river. Eventually, however, the mass flux to the river will decrease as the effects of slow source decay overcome the effects of increased river discharge. By the time the system reaches steady state (predicted by the model to be about

2020), the mass flux to the river will be decreasing steadily and will continue to decrease as the source is depleted.

- Overall, the model likely presents a conservative estimate of actual conditions present at the site. For example,
  - The model predicts the presence of chlorobenzene in some portions of the Middle Hydrogeologic Unit (MHU) where the actual plume data shows no plume.
  - Based on calibration results, the model uses a lower (slower) biodegradation rate than the Illinois Tiered Approach to Corrective Action Objectives (TACO) (35 IAC 742) standard.
  - Maximum detected concentrations from 1980s to 2006 were used to calculate source concentrations over time for the slow source decay term. For some constituents, this resulted in higher 2006 concentrations than actual measured values.

As noted above, the regional groundwater fate and transport model was calibrated for the following seven constituents: chlorobenzene, 1,4-dichlorobenzene, tetrachloroethene, trichloroethene, cis-1,2-DCE, vinyl chloride, and 2,4-D. All seven are Sauget Area 1 indicator constituents. Benzene and 4-chloroaniline are the two Sauget Area 1 indicator constituents that were not included in the model calibration.

#### **6.4.3.4 Updated Groundwater Model (GSI, 2012)**

Based on the IEPA memorandum (IEPA, 2011), the following changes were made to the groundwater model:

- Pumping rates for the pumping centers representing ongoing highway dewatering projects in the East St. Louis area, assumed to be withdrawn from all three layers, were revised as requested by IEPA. As a conservative estimate, total industrial pumping rates (including highway dewatering projects) from 1960 through 1994 were obtained from historical published records. Pumping rates from 1995 through 2038 were obtained from the IEPA memorandum (IEPA, 2011). Additionally, the IEPA ratio of pumping between pumping centers was retained for the entire modeling period (1960 through 2038), with respect to installation years for the various dewatering centers.
- The highway dewatering system was assumed to stay on for the duration of the modeling (i.e. through 2038) rather than terminating in 2010, as simulated in the 2008 groundwater model.

Modifying pumping rates can have a considerable impact on model calibration, resulting in significant changes to future predictions. Therefore, the following actions were taken to determine the impact changing dewatering system pumping rates have on model calibration.

1. The model was re-run for the constituents of interest: chlorobenzene; 1,4-dichlorobenzene; 2,4-D; PCE; TCE; 1,2-DCE; and vinyl chloride, and
2. Root mean square (RMS) and mean residual errors of the updated model were then compared to the errors obtained from the 2008 model to determine whether the updated pumping rates had any impacts on model calibration. This work demonstrated that the model did not need to be re-calibrated (GSI, 2012).

The updated regional groundwater flow and transport model was then used to determine the percent of dissolved constituent mass flux captured by the GMCS (GSI, 2012).

The MODFLOW model was run under transient conditions from 1960 to 2038 (GSI, 2008b). RMS and residual errors for each of the seven COI were compared to errors obtained for the 2008 model. Overall, updating highway dewatering well pumping rates improved the calibration of the groundwater fate and transport model for chlorobenzene and 1,4-dichlorobenzene, while the calibrations for 2,4-D; PCE; TCE; DCE; and vinyl chloride remained relatively unchanged.

#### **6.4.3.5 Modeled Isoconcentration Contour Maps for 2006 and 2038**

Figures 6-1 through 6-42 show modeled isoconcentration contour maps for 2006 and 2038 for the seven calibrated constituents, with separate maps for each constituent for the SHU, MHU, and DHU. Each figure includes a map showing the modeled isoconcentration contours for the updated model (GSI, 2012) and the original model (GSI, 2008b).

Chlorobenzene is the most widespread of the seven calibrated constituents. The core of the modeled chlorobenzene plume in the MHU and DHU from the Sauget Area 1 sources is a 10 mg/L isoconcentration contour that extends west of Sauget Area 1 onto Lot F (see Figures 6-3 through 6-6). Comparison of the modeled 2006 and 2038 plumes show that the chlorobenzene plume core from Sauget Area 1 sources is relatively stable. The results are similar for 1,4-dichlorobenzene, except that the modeled plume concentrations are lower compared to chlorobenzene (Figures 6-9 through 6-12).

The modeled chlorinated ethene plumes (Figures 6-19 through 6-42) are relatively dilute except in the SHU at the Sauget Area 1 source areas. The plume core for chlorinated ethenes is represented by the 0.1 mg/L isoconcentration contour for 1,2-DCE in the MHU (see Figures 6-33 and 6-34). The modeled results for 2006 and 2038 predict dowgradient expansion of relatively dilute trichloroethene and 1,2-DCE plumes from Site G in the MHU and DHU during that time period (see Figures 6-27 through 6-30 and Figures 6-33 through 6-36).

The modeled results for 2,4-D (Figures 6-13 through 6-18) show a very small plume in the SHU in the immediate vicinity of Site G in 2006 that persists to 2038. However, the modeled results show no plume of 2,4-D in the MHU or DHU.

### **6.5 Mass Flux to Mississippi River and Mass Flux Removed by Natural Attenuation**

#### **6.5.1 Mass Flux Discharged to Mississippi River**

The 2012 updated regional groundwater flow and transport model (GSI, 2012) was used to quantify the percent of dissolved constituent mass flux captured by the GMCS for each source area in the Sauget region. For this purpose, all other source areas were removed and the 2003 to 2038 segment of the model was run with a) the GMCS in place and b) the GMCS off. Quantitative predictions were made using the model for all source areas, for Sauget Area 1 source areas only, for Sauget Area 2 sources only (combined), Sauget Area 2 source areas (Site R only), Sauget Area 2 source areas (Site O only), Clayton Chemical source areas only, and Krummrich source areas only. Results of the quantitative predictions are presented in the 2012 memo regarding the updated groundwater model (GSI, 2012). For Sauget

Area 1 sources only, overall, when all modeled constituents are included, 73% of the total plume mass flux that would have discharged to the river in 2038 without the GMCS is predicted to be captured by the GMCS. Benzene and 4-chloroaniline were the only Sauget Area 1 indicator constituents that were not included in the calibration, so the mass flux predictions do not include those two constituents.

Based on results presented in the 2012 update of the groundwater model (GSI, 2012), the mass flux from the Sauget Area 1 sources to the Mississippi River is a relatively small percentage of the mass flux to the River from non-Sauget Area 1 sources (e.g., Sauget Area 2 and Krummrich). The tables below were taken from the 2012 update of the groundwater model (GSI, 2012) and summarize the modeled mass flux from the Sauget Area 1 plumes to the Mississippi River with the GMCS off and with the GMCS on.

Modeled Mass Flux To River from Sauget Area 1 Plumes with GMCS OFF (kg/yr)								
	All 7 COCs	2,4-D	CB	1,2-DCE	DCB	VC	TCE	PCE
2006	236	0	120	16	13	88	0	0
2010	206	0	94	24	10	74	3	0.4
2020	232	0	81	55	9	79	7	0.7
2030	201	0	70	47	8	69	6	0.6
2038	181	0	63	42	7	62	6	0.5

CB = chlorobenzene; DCB = 1,4-dichlorobenzene; 2,4-D = 2,4-Dichlorophenoxyacetic acid; PCE = tetrachloroethene; TCE = trichloroethene; 1,2-DCE = cis-1,2-Dichloroethene; VC = vinyl chloride; kg/yr = kilograms per year.

Modeled Mass Flux To River from Sauget Area 1 Plumes with GMCS ON (kg/yr)								
	All 7 COCs	2,4-D	CB	1,2-DCE	DCB	VC	TCE	PCE
2006	94	0	37	8	3	46	0	0
2010	72	0	30	6	2	34	0.06	0.009
2020	62	0	26	6	2	27	0.2	0.02
2030	55	0	23	6	2	24	0.2	0.01
2038	50	0	21	5	2	22	0.2	0.01

Percent Mass Flux from Sauget Area 1 Plumes Captured by GMCS (%)								
With GMCS <u>ON</u>	All 7 COCs	2,4-D	CB	1,2-DCE	DCB	VC	TCE	PCE
2006	60	100	69	50	76	48	100	100
2010	65	97	68	75	76	54	98	98
2020	73	98	67	88	77	66	97	98
2030	73	98	67	88	76	65	97	98
2038	73	98	67	88	77	65	97	98

Modeled mass flux results for all seven constituents in the Sauget Area 1 plumes were as follows:

<b>Mass Flux for Sauget Area 1 Plumes Based on Groundwater Flow and Contaminant Transport Model</b>	
	<b>All 7 COCs (kg/yr)</b>
<b>Modeled Mass Flux To River in 2006 with GMCS OFF</b>	<b>236</b>
<b>Modeled Mass Flux To River in 2006 with GMCS ON</b>	<b>94</b>
<b>Mass Flux Removed by GMCS in 2006</b>	<b>142</b>

**Key Point**

For all seven modeled constituents, modeled mass flux to the Mississippi River in 2006 with the GMCS on was 94 kg/year, and mass flux removed by the GMCS in 2006 was 142 kg/year. These calculations are for the Sauget Area 1 plumes only and are based on the updated groundwater model (GSI, 2012).

### 6.5.2 Calculated Mass Removal by Natural Attenuation in 2006

For the Sauget Area 1 plumes, mass removal by natural attenuation in 2006 can be estimated based on the calculated mass flux in the MHU and DHU at the Site I source area (see Section 6.2.1.3) and modeled mass fluxes as discussed in the previous section:

<b>Calculated Mass Removal by Natural Attenuation for the Sauget Area 1 Plumes in 2006</b>	
	<b>Mass Flux (kg/yr)</b>
<b>A: Calculated Mass Flux from Site I Source Area (GSI, 2005)</b>	<b>2,780</b>
<b>B: Modeled Mass Flux To River in 2006 with GMCS On</b>	<b>94</b>
<b>C: Modeled Mass Flux Removed by GMCS in 2006</b>	<b>142</b>
<b>Estimated Mass Removal by Natural Attenuation in 2006 ( = A - B - C )</b>	<b>2,554</b>

Based on this calculation, the rate of mass removal by natural attenuation in 2006 is estimated to have been 2,554 kg/year.

## 7.0 CONCEPTUAL SITE MODEL

The Conceptual Site Model for Sauget Area 1 is based on findings of the Remedial Investigation and focuses on source areas and groundwater. The Conceptual Site Model is described below and illustrated on Figures 7-1 and 7-2.

**Source Areas** – The disposal areas at Sites G, H, I South, and L are contaminant source areas and contain municipal and industrial waste materials, including crushed or partially crushed drums, drum fragments, uncontained soil and liquid wastes, wood, glass, paper, construction debris, and miscellaneous trash.

Site I North and Site N are not considered to be contaminant source areas. Site I North contains inert fill materials such as brick, pieces of concrete, large concrete slabs, rebar, sheet metal, wood, fill soil, and gravel. Site N, which is located on property formerly owned by the H. Hall Construction Company, was primarily used for disposal of construction debris. The waste materials found in Site N included soil, brick, concrete, metal, tires, and wood, as well as some crushed drums and drum fragments, including a few that contained a pasty whitish material that could have been painting waste.

Sites G, H, I South, I North, L, and N cover an area of 27.91 acres broken down as follows: Site G, including G West - 3.32 acres, Site H - 4.87 acres, Site I South - 8.79 acres, Site I North – 5.87 acres, Site L - 1.08 acres, and Site N – 3.98 acres.

Based on the findings of the DNAPL characterization study, the upper-bound estimate of the volume of DNAPL-containing waste and aquifer matrix is approximately 1.7 million cubic yards, within a total area of approximately 15 acres at portions of Sites G, H, and I South. Pooled DNAPL and/or LNAPL are or may be present in waste materials at portions of Sites G and I South. Pooled DNAPL is present at the alluvial aquifer/bedrock interface beneath a portion of Site I South near well BR-I and is potentially present beneath a portion of Site G near well BR-G.

Residual DNAPL is or may be present as small, discreet blobs and/or ganglia in the unsaturated zone and in the SHU, MHU, and DHU underlying portions of Sites G, H, and I South. Constituents that may be the result of DNAPL dissolution are present in the Alluvial Aquifer beneath and/or downgradient of Sites G, H, I South and/or L.

Solutia remediated Dead Creek Segments B, C, D, E and F by removing 46,000 cubic yards of sediments in 2001-2002 and 12,400 cubic yards of sediments and creek bottom soil in 2005-2006. Dead Creek, Borrow Pit Lake, and the floodplain soils along Dead Creek are not ongoing sources to groundwater, and other pathways for these areas are assessed in the human health risk assessments and ecological risk assessments that are summarized in Sections 8.0 and 9.0 of this report.

**Groundwater** – Groundwater in the Alluvial Aquifer moves to the west toward the Mississippi River. VOC and SVOCs are the principal contaminants in groundwater. As the plumes from Sauget Area 1 move toward the west, they combine with plumes originating from sources at other sites in the Sauget region, including Sauget Area 2 Sites, Clayton Chemical, and the W.G. Krummrich facility.

Mass flux of site constituents from the Sauget Area 1 source areas due to groundwater flow was estimated to be 2,780 kg/year based on a mass flux study at Site I South. The same study indicated that mass flux due to leaching of unsaturated source materials is relatively small (1% for chlorobenzene and 1.5% for 1,4-dichlorobenzene) compared to the mass flux of these constituents from the source area due to groundwater flow.

The plume from Site I South and the plume from Sites G, H, and L are intercepted by the GMCS at Site R, located approximately 5200 feet downgradient of the western boundary of the Sauget Area 1 sources. Based on fate and transport modeling, mass flux removed by the GMCS in 2006 from the Sauget Area 1 plumes was 142 kg/year, and mass flux to the Mississippi River in 2006 from the Sauget Area 1 plumes was 94 kg/year. Natural attenuation processes removed an estimated 2,554 kg/yr of site constituents in 2006. Based on results presented in the groundwater modeling report (GSI, 2008), the mass flux from the Sauget Area 1 sources to the Mississippi River is a relatively small percentage of the mass flux to the River from non-Sauget Area 1 sources (e.g., Sauget Area 2 and Krummrich).